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THE IMPACT OF PRESCRIBED FIRE FOLLOWING EITHER HERBICIDE OR THINNING TREATMENTS ON BUNCHGRASS AND FORESTED ECOSYSTEMS IN THE SAWMILL CREEK RESEARCH NATURAL AREA

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The Impact of Prescribed Fire Following Either Herbicide or Thinning Treatments On Bunchgrass and Forested Ecosystems in the Sawmill Creek Research Natural Area

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Executive Summary

The Sawmill Creek Research Natural Area was designated to provide examples of several native bunchgrass and open canopy forest habitat types on the Bitterroot National Forest in western Montana. However weed invasion and formation of a Douglas-fir fuel ladder were degrading vegetative composition and structure such that the existing vegetative state was increasing less similar to the potential natural communities. Weed management and silvacultural methods were used in an attempt to return the vegetation to a more natural state and slow future degradation. Herbicides, biocontrol insects, weed pulling, thinning, and burning were the primary techniques employed in the restoration efforts. An extensive monitoring system was installed to characterize the vegetation before the treatments were initiated and to follow the response to these treatments. Baseline community composition of the first set of monitoring plots was measured in 1995. Treatment response measurements of various monitoring plots and transects continued through 2006.

Broadcast herbicide spraying in fall of 1996 or fall of 1998 from the ground, and spraying from a helicopter in fall of 2004 was highly effective in suppressing the primary target weed spotted knapweed. Native bunchgrass production increased dramatically on this important elk winter range after the knapweed competition was reduced by spraying. Non-target forb abundance declined slightly in the first growing season after each spray event, but recovered to pre-spray levels or exceeded pre-spray levels in subsequent growing seasons. Plant diversity declined following the initial herbicide treatment with Tordon, but cumulative drought during the last half of the monitoring period had more impact on diversity than the Tordon treatment. The second herbicide treatment using Transline did not reduce plant diversity. After each herbicide spraying event the plant community composition (species present and their relative abundances) increased in similarity to the potential natural communities as defined by habitat type definition plots. The herbicide induced shift toward the potential natural community was not persistent. Heavy elk grazing, burning, knapweed reestablishment, and prolonged precipitation deficits reversed much of the floristic trajectory gains relative to the potential natural vegetation state. Nonetheless, at the conclusion of monitoring the sprayed plots were more similar to the potential natural community than were weedy plots that had not been sprayed. Although the forested areas were disturbed by silvacultural and burning treatments the weed management strategy prevented any weed increases in the forested areas. This project represents successful restoration and maintenance of natural grassland and forest communities, and is the only long term monitoring data set validating such efforts.

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Introduction

The Forest Service established the 270 acre Sawmill Research Natural Area in the Sapphire Range of the Bitterroot National Forest because it was one of our best remaining examples of native bunchgrass and open canopy forest habitat types. The RNA is also an important elk winter range. However, invasion of the RNA by exotic plants was degrading the grasslands, and Douglas-fir encroachment of the forested ravines, because of fire suppression, was altering the species composition and structure of the forest types. We mapped the distribution of ten invasive weeds in 1994 and developed a restoration plan in 1995. The overall strategy was to first suppress the noxious weeds in the grasslands, reduce stand density in the forested ravines by thinning, and then return fire through prescribed burning to the grasslands and the forested areas. This was an integrated weed control and restoration demonstration project at the management unit scale, in addition to a focused restoration effort for the altered ecosystems of this RNA. We installed an extensive network of vegetation monitoring plots to provide scientific documentation of progress in returning the potential natural vegetation. This would allow for an assessment of the impact of future treatments and disturbance, natural or otherwise. Our intent was that site tours and technical reports be used for public and professional staff education, developing environmental impact statements, and restoration planning.

We began plan implementation in 1995 by setting up herbicide test plots and introducing knapweed biocontrol insects. The 1996 trial spray treatments were successful in driving the plant community composition to a state more similar to the potential natural vegetation as defined by the Mueggler and Stewart habitat types found on the RNA. In 1998 nearly the entire grassland (~160 acres) was sprayed. Bunchgrass cover was restored to the site and native forb diversity was maintained. The biomass that had been represented as coarse-stemmed knapweed was converted to fine grass. In 1999 the Douglas-fir understory was slashed and piled, and selected larger Douglas-firs were girdled. The piles were burned in the fall of 1999. The Stevensville Ranger District broadcast burned the upper 2/3 of the RNA in November 2001. The forested ravines below the lower road were burned on April 5, 2004 by the Stevensville Ranger District in cooperation with Mick Harrington from the Missoula Fire Sciences Laboratory. We have not been able to burn the grasslands below the lower road because fuels have been insufficient to carry the fire under cool season conditions. The entire grasslands, including the initial herbicide test plots, and forested ravines were helicopter sprayed with Transline at 2/3 pint/acre on October 1, 2004.

Changes in species composition, biomass production, and fuel loads during the course of this restoration demonstration project were measured by an extensive network of sampling plots and transect. We made measurements on a near-yearly basis depending on availability of funding from 1995 through 2006. This twelve year monitoring study of weed management and native plant community restoration is unique in its duration and detail.

Site Description

Sawmill Creek Research Natural Area (RNA) is located in the northeastern portion (T8N,R18W Sect 18) of the Bitterroot National Forest on the Stevensville Ranger District in western Montana. It is primarily a south facing slope system. Several forested ravines dissect a montane grassland. The area totals 270 acres. The RNA supports a mosaic of dry conifer forest and mountain grassland habitat types. The most common tree species in 1999 was Douglas-fir (*Pseudotsuga menziesii*) making up 70% of the stand density. Twenty-two percent of the stand was ponderosa pine (*Pinus ponderosa*), the historic dominant. The remaining 8% was Rocky Mountain juniper (*Juniperus scopulorum),* which has increased along with Douglas-fir in the last 75 years during the fire suppression era. The trees form park-like stands on dry sites and closed canopy forests on the more mesic ravine sites but the Douglas-fir proliferation has caused increased competition and ladder fuels throughout the RNA. The mountain grasslands that should be dominated by bluebunch wheatgrass (*Agropyron spicatum*), Idaho fescue (*Festuca idahoensis*) and rough fescue (*Festuca scabrella*) occupy about 40% of the RNA.

The area has been subjected to grazing by both livestock and elk herds. There is no written record for the area prior to 1944 but it is said that it was used heavily for years by private landowners. Records of the area were kept from 1944 on by the BNF, and provide a history of only moderate to light livestock use after the 1950's. In May of 1992 the area was designated as a RNA to provide an example of five natural communities:

rough fescue/Idaho fescue h.t.
Idaho fescue/bluebunch wheatgrass h.t.
ponderosa pine/Idaho fescue h.t.
Douglas-fir/Idaho fescue h.t.
Douglas-fir/bluebunch wheatgrass h.t.

The major objective of establishing Sawmill Creek RNA was to maintain and preserve these habitat types in as near an undisturbed (by modern humans) condition as possible.

Although the Sawmill RNA was believed to contain the best remaining example of rough fescue/Idaho fescue habitat type on the Bitterroot National Forest, and superior examples of the other four habitat types, like most of the western US, it has not completely escaped the invasion of exotic weed species. In 1994 we mapped the distribution of ten of the most problematic exotic species that had invaded the unit. A map showing the distribution of spotted knapweed in 1994 is included as Appendix Figure 19.

Target	Acres	Objective
spotted knapweed (*Centaurea maculosa*)	153 acres	suppress
leafy spurge (*Euphorbia esula*)	<0.01 acres	eradicate
sulfur cinquefoil (*Potentilla recta*)	0.28 acres	suppress

dalmatian toadflax (*Linaria dalmatica*)	<0.01 acres	eradicate
St. Johnswort* (*Hypericum perforatum*)	4.2 acres*	contain
common tansy (*Tanacetum vulgare*)	<0.01 acres	contain
houndstongue (*Cynoglossum officinale*)	<0.01 acres	contain
musk thistle (*Carduus nutans*)	0.24 acres	suppress
Canada thistle (*Cirsium arvense*)	<0.01 acres	suppress
common mullein (*Verbascum thapsus*)	14.2 acres	tolerate

* also called goatweed, 2.7 acres within the RNA and 1.5 acres along the west boundary

Suppression, containment, or eradication where feasible, of most of these exotics was desirable to obtain the principal management goal of maintenance of the natural climax communities for this site.

Douglas-fir establishment in the understory had been extensive throughout the forested areas of the RNA. Dwarf-mistletoe and several root diseases were prevalent in all size classes of Douglas-fir. Removal of understory and midstory Douglas-fir was necessary to reduce the probability of stand replacing fires and decrease the competitive pressure on ponderosa pine. Conifers had also been encroaching into the grassland habitat types and junipers are now a significant component at the lower elevations.

Methods

Study design and sampling methods

This is essentially a monitoring study to determine the temporal response of the vegetation to management actions intended to preserve the native plant communities that were the reason for establishing this Research Natural Area. The rationale for designating RNA's is to allow natural process to proceed or be maintained independent of anthropogenic factors, but management can intercede to protect the RNA from external non-natural factors like weed invasion or consequences of natural fire suppression. However RNA policy interpretation restricted rigorous experimental designs with treatments and formal spatial controls. Accordingly, although we have temporal (pre-spray and pre-burn) control data, our opportunity for spatial controls is limited to measurement of plot or transects in areas that cannot be sprayed or otherwise treated because of their location or other logistic constraints. The spatial control or check plots we do have are opportunistic under these policy interpretation constraints.

Plant community composition was first determined in 1995 prior to any herbicide treatment of the permanent test/demonstration plots or spraying of the extensive grassland habitats. Permanent monitoring plots were established in each of the major habitat types. Plots were 0.1 acre (66'x66'). Nineteen plots were placed in the grassland habitat types and three in open forest habitat types. The plots were located using a stratified random design. Each of the twenty-two permanent monitoring plots has five randomly placed transects with five microplots per transect. Plot corners and 5 random

transects per plot were permanently marked with painted iron rebar. Five 10x20 inch microplot locations per transect were permanently marked with brightly painted nails to allow precise relocation of sampling frames each year. Species composition was determined by Daubenmire canopy cover techniques.

We used the "Cover Microplot" and "Short Nested Microplot" sampling protocols developed as part of the standard Region 1 ECODATA methods (Hann & Jensen 1987) for grassland sampling.

Short Nested Microplot data was used to monitor target exotics and dominant natives that define the climax communities. These data are used to answer the question: are targeted exotics increasing or decreasing in the RNA? Goatweed (St. Johnswort) plots were read periodically through 2006. Three short nested plots were located in goatweed colonies that received their first herbicide treatments in 1995. Six short nested plots were located in areas with high weed densities including areas where cheatgrass (*Bromus tectorum* L.) density was high, and on sites where landscape features created special interest management areas (i.e. open ridgelines isolated by forest cover). Three short nested plots were also established in not-weedy areas to provide reference data from untreated portions of the RNA. The main 0.1 acre plot types, purpose, treatments, and sampling histories are summarized in the Appendix Table 17.

Full community measurement "Cover Microplots" plots were established in 1995 and 1996 to determine if the grassland plant communities were becoming more or less similar to the potential natural communities. A double stratified random design was used to locate ten of these plots in the weediest areas of 3 different grassland and shrub habitat types. These measurements were repeated in 1998, 1999, 2001, 2002, 2004, 2005, and 2006 to evaluate the response of the entire plant community to the fall 1996 and fall 2004 herbicide treatments.

Elk exclosures were built around full community baseline monitoring plots at four locations. Each enclosure was paired with an adjacent, non-enclosed plot, and pair locations stratified by habitat type (Appendix Table 17). The elk enclosures are 75 ft × 75 ft and 6 ft tall (4 ft field wire along the bottom, with 3 strands of barbed wire above). Herbaceous standing crop in the 8 plots comprising the elk exclosure study was estimated by double sampling (Francis et al. 1979) for the following categories:

1) bluebunch wheatgrass (AGRSPI)
2) Idaho fescue (FESIDA)
3) rough fescue (FESSCA)
4) other grasses
5) spotted knapweed (CENMAC)
6) other forbs

Standing crop sampling is done near the period of peak biomass, the first sample having been before the fall 1996 herbicide applications. We made ocular estimates of green weight in 25 microplots (25 × 51 cm frames) per monitoring plot. Five randomly

selected microplots per monitoring plot were also clipped. We calibrated estimated green weights to oven-dry weights by linear regression. This peak biomass sampling was then repeated seven more times, in 1997, 1998, 1999, 2002, 2004, 2005, and 2006

In 1998 fourteen new transects were established to monitor grassland response to the herbicide applications over the extensive grassland area that would be sprayed with Tordon in fall 1998. Transects were set in pairs forming two sides of 0.1 acre plots at seven locations. Transect layouts were the same as used for the transects within the previously established monitoring plots: length 66 ft., 5 microplot locations at 12 ft. intervals, microplots 10 in. x 20 in. Canopy cover classes were estimated for 7 individual species and 4 other vegetation life form categories. Forty additional transects initially established for determining fuel loads throughout the entire grassland were also used to measure spraying efficacy and non-target plant response in 2004 and 2005

In addition to the permanent plant community plots and transects, "observation posts" were established in the small colonies of weeds that were targeted for eradication. There initially were eight colonies of dalmatian toadflax (*Linaria dalmatica* (L.) Mill.). There was only one leafy spurge (*Euphorbia esula* L.) colony. The initial centers of the colonies were permanently marked with steel fence posts. The usual ECODATA plots are not appropriate due to the small size of these colonies. At each observation post we record location and general site data, colony dimensions, approximate abundance of the target weed. These points were inspected three times (spring, summer, and fall) per year through 1999, then during the summer through 2005. Additional dalmatian toadflax colonies appeared during the duration of the monitoring study and these were added to eradication observation post set.

Forest understory sampling began in 1999 to characterize the entire forest understory response to herbicides, forest canopy thinning, and prescribed burning. The method is similar to the Daubenmire technique used for the main 0.1 acre plots, except a larger 143cm x 70 cm (one square meter total) frame was used, with four frames per plot or location. There are 20 plots in the west-most forested ravine, and 25 to the east in the forested ravine in the center of the RNA.

Herbicide treatments

In the fall of 1996 we made test broadcast treatments for spotted knapweed control on 14 experimental monitoring plots. The timing corresponded to fall regrowth of knapweed rosettes. Each plot was treated with picloram (Tordon 22K) at the recommended rate for control of spotted knapweed (0.25 lb active ingredient/acre or 1 pint/acre Tordon 22K). The application dates were from September 26 through 30. An 80 by 80 foot area centered on each 1/10 acre plot was treated so there was a sprayed buffer between the surrounding weeds and the sampling plot.

During the period 9/26-10/31/98 the extensive grassland portions of the RNA were broadcast sprayed. The extensive grassland treatments had to be applied in a manner

that avoided spraying a certain number of the permanent monitoring plots and biocontrol release plots. Herbicides were sprayed when weather conditions were favorable. ATV boom, truck-mounted handguns, and Solo backpacks were used. Most of the acreage was treated with the ATV-mounted boom. Tordon was applied at 1 pint / acre to 133.5 acres and Transline at 2/3 pint / acre to 18.9 acres. The Transline was used in the grassland-forest ecotones and the Tordon in the open grasslands. Total calculated coverage was 152.4 acres of the nominal 156 acres targeted for treatment.

Tree thinning was done in the ravines during the summer of 1999 and slash piles formed for burning in late fall. Prior to burning the slash piles in the west and central ravines, the areas of forest openings with knapweed were sprayed with Tordon at 1 to 2 pts/acre and Transline at 2/3 pt/acre. The goal of spot spraying in the forest openings was to reduce weed spread into the bare soil of slash pile burn spots and other areas disturbed by the silvacultural preparations for broadcast burning in 2001.

The entire grasslands (except for the buffer strip immediately above Sawmill Creek), including the initial herbicide test plots, and the forested ravines were helicopter sprayed with Transline at 2/3 pint/acre on October 1, 2004.

Other Weed Treatments

Knapweed biocontrol insects, *Agapeta zoegana* (knapweed root moth) and *Cyphocleonus achates* (knapweed root weevil) were released on the site starting in 1996 (Rice 2000). *Urophora* (knapweed seed head gall flies) species were already well established on the spotted knapweed as of 1994. *Larinus spp.* (*L. minutes* and/or *L. obtusus*) (lesser knapweed weevil and/or blunt knapweed weevil) were in evidence on the RNA by ~2000. *Chrysolina* (Klamath weed beetles) were already present on goatweed at the start of the project.

Hand digging, pulling, and limited spot spraying have been used to suppress small colonies of other noxious weeds found on the RNA. The road prisms have also been periodically sprayed with Transline or Tordon.

Burn and forest thinning treatments

The Stevensville Ranger District and the RMRS Fire Sciences Laboratory conducted thinning to reduce competition and ladder fuels and made other broadcast burn preparations in the forested ravines in 1999. Douglas-fir, junipers, and small ponderosa pine were thinned and piled in the west and central forested ravines during the summer. The slash piles, some ladder fuels, and downed logs were burned in the fall of 1999. Some larger Douglas-fir were girdled and left standing to reduce competition, seed supply, and disease source.

The upper two-thirds of the unit were burned on November 7 and 9, 2001. This was primarily grassland habitat types and a small section of forested ravine. The burned forested ravine area included 8 of the 45 forest understory plots.

The forested ravines below the lower road were burned on April 5, 2004 by the Stevensville Ranger District in cooperation with Mick Harrington from the Missoula Fire Sciences Laboratory.

Fuel sampling

The basic fuel transect is 66 foot long on contour with the slope. The beginning and end of transects are marked with a red rebar. Pre-existing plot/transect markers were used to set up some of the fuel transects. A total of forty-five fuel transects were initially (2001) established. Thirty-five transect were in the two-thirds of the grassland above the lower road. Ten transect were in the third of the grassland below the lower road. Seventeen additional fuel transects were installed below the road in 2002. The fuel transect were later used to help assess the efficacy of the fall 2004 helicopter application of Transline throughout the extensive grassland. Five microplots (10 x 20 inches each) are clipped at predetermined intervals along each transect. The plant material from each microplot is separated into five fuel categories and composites formed at the transect level.

1. All grasses except cheatgrass
2. Cheatgrass
3. Spotted knapweed
4. Other forbs
5. Litter (detached plant material)

Fuel categories 1-4 include all attached plant material even if horizontal on the ground. Samples were forced-air oven dried to a constant weight for three days at 40 degrees Centigrade.

Data analyses

Plant community data was ordinated by global non-metric multidimensional scaling (Kruskal & Wish 1978). Floristic trajectories and similarity to the species composition of the Mueggler and Stewart (1980) habitat type definition plots were illustrated with the NMS ordination graphics. The ordinations were calculated with the fewest dimensions (two or three) that resulted in a stress less than 20. Limiting the dimensionality facilitated graphic interpretation of the floristic trajectories of the test plots. Multivariate differences in species composition of plot groups were tested by multi-response permutation procedures (Mielke and Berry 2001, McCune et al. 2002). Ordinations and multi-response permutation procedures were calculated using PC-ORD 4.0 (McCune and Mefford 1999).

The analyses of variance, t tests, and pairwise comparisons were performed using SPSS 14.

Results and Discussion

Permanent plot biomass response

Net standing crops of herbaceous vegetation were estimated by double sampling of full community plots. The measured results are pounds per acre averages of net biomass for study years 1996-1999, 2002, and 2004-2006 (Table 1). Average biomass in 2005 was at its highest level recorded in this study and the lowest in 2006. Grasses showed the largest increases in biomass in 2005, but forbs were also at their highest level excluding 2004 values. The decline in total production for 2006 was also measured at numerous other bunchgrass sites being studied by this investigator. Dry and warm weather in May 2006 appears to have arrested growth of perennial grasses. The large decrease in growth from 2005 to 2006 evidenced by the annual biomass data was confirmed by the canopy cover data which indicated a 70%+ reduction in grass canopy cover from 2005 to 2006 (Table 2). The maximum annual variability in bunchgrass production is known to be approximately four-fold. May and June are the principal months for growth of bunchgrasses. Precipitation during May 2005 (2.94 in.) was well above the long term average (1.49 in.), but below long term average for May 2006 (1.14 in.) (Table 2). June precipitation in both years was half of the long term average.

The controls (#918 & 920) were inadvertently sprayed with a partial herbicide dose in the fall of 2004 by drift from the helicopter so there was almost no knapweed growth in 2005 in these plots (Table 1). Knapweed on the low rate drift impacted "no-spray" weedy control plots began to recover in 2006. The #920 control had a 96% frequency of occurrence of spotted knapweed, mostly small seedlings, but only 1.7% canopy cover so the knapweed biomass was still suppressed. Plot #907 was substituted in 2006 for #920 as a "no-spray" biomass production control. Plot #907 had been sprayed only once ten years ago in the fall 0f 1996. Knapweed production in plot #918 by 2006 appeared to have fully recovered form the partial rate drift exposure in 2004 so we continued to use it as a control data point.

A four life form summary graph with the production data normalized to remove precipitation driven differences in total annual production is presented as Figure 1; the cheatgrass over time line is based on absolute canopy cover rather than biomass. Perennial grasses showed a large increase in percent of total biomass following both herbicide treatments. The knapweed production collapsed to very low levels in the first growing season after the fall 1996 Tordon spraying. The partial reestablishment of knapweed in the years following the first treatment was entirely alleviated by the second spray treatment with Transline in the fall 2004. Even though non-target forbs showed a small decrease in percent biomass following the first (fall 1996) and second (fall 2004) spray treatments, the overall trend has been for maintenance or an increase in the proportionate biomass of non-target forbs. Because a small amount of cheatgrass is included with other grasses in biomass measurements it is still important to see if the increases in grasses seen after herbicide treatments are also caused by increases in cheatgrass production. Though some cheatgrass has been present in the majority of plots, cheatgrass canopy cover remains ecologically insignificant (~1%) and has not increased at all over the last ten years.

Table 1. Standing crop production summary (lbs/ac. dry weight) for Sawmill test plots.

	AGRSPI	FESIDA	FESSCA	*3 Bunch-Grasses	*Other Grasses	All Grasses	CENMAC	Other Forbs	TOTAL
1996 enclosed	228	153	66	447	62	509	473	252	1,234
1996 open	199	87	51	337	76	414	521	220	1,155
Average before spraying	214	120	58	392	69	462	497	236	1,194
1997 enclosed	318	189	147	654	172	826	8	118	951
1997 open	275	123	119	517	283	800	15	138	953
Average one year post spray	297	156	133	586	227	813	11	128	952
1998 enclosed	425	302	244	970	197	1,168	38	193	1,399
1998 open	360	145	132	637	263	900	110	204	1,214
Average 2 years post spray	392	223	188	804	230	1,034	74	199	1,306
1999 enclosed	387	255	141	783	178	961	193	242	1,397
1999 open	343	138	74	556	251	807	330	240	1,377
Average 3 years post spray	365	197	108	669	215	884	262	241	1,387
2002 enclosed	183	178	189	550	54	604	121	159	884
2002 open	223	94	99	416	112	528	200	148	876
Average 6 years post spray	203	136	144	483	83	566	161	154	880
2004 enclosed	204	161	267	632	44	676	171	234	1,081
2004 open	276	105	87	468	68	536	233	585	1,355
Average 8 years post spray	240	133	177	550	56	606	202	409.5	1,218
2005 enclosed	189	614	540	1343	114	1457	0	294	1,751
2005 open	238	296	273	806	179	986	0	288	1,273
Average 1 year post secondary spray	214	455	407	1075	147	1222	0	291	1,512
2006 enclosed	96	85	190	370	47	417	4	132	553
2006 open	105	46	112	262	93	356	2	154	512
Average 2 year post secondary spray	101	67	151	316	70	387	3	143	533
No-spray controls:									
Control, 1999 - #920	8	0	0	8	96	104	1,179	352	1,635
Controls Avg, 2002 #918 & #920	61	0	0	61	100	161	429	101	692
Controls Avg, 2004 #918 & #920	133	1	23	157	143	300	414	105	819
Controls Avg, 2005 #918 & #920†	183	0	0	183	294	478	1	314	793
Controls Avg. 2006 #918 & #907†	45	11	5	60	118	178	281	80	783

*Bunchgrasses are the three habitat type indicator bunchgrasses, Other Grasses are primarily *Koeleria cristata* and *Poa secunda*, except for the no-spray weedy controls which have considerable amounts of cheatgrass (*Bromus tectorum*).

† The controls #918 & #920 received spray drift in the fall of 2004 from the helicopter, #907 was treated only in 1996 and replaced #920 as a "no-spray" control for 2006.

Table 2. Rainfall[†] and decrease in average canopy cover from 2005 to 2006.

Species or Lifeform	2005 Mean C.C.	2006 Mean C.C.	% C.C. Reduction From 2005
AGRSPI	8.2	1.8	78
FESIDA	11.4	2.6	77
FESSCA	15.7	3.4	78
Other Grams	7.0	1.7	76
Other Forbs	9.2	4.3	53
Rainfall (in.)	**2005**	**2006**	**Long Term (1911-1997)**
May	2.94	1.14	1.49
June	0.88	0.85	1.64

[†]Stevensville Ranger Station

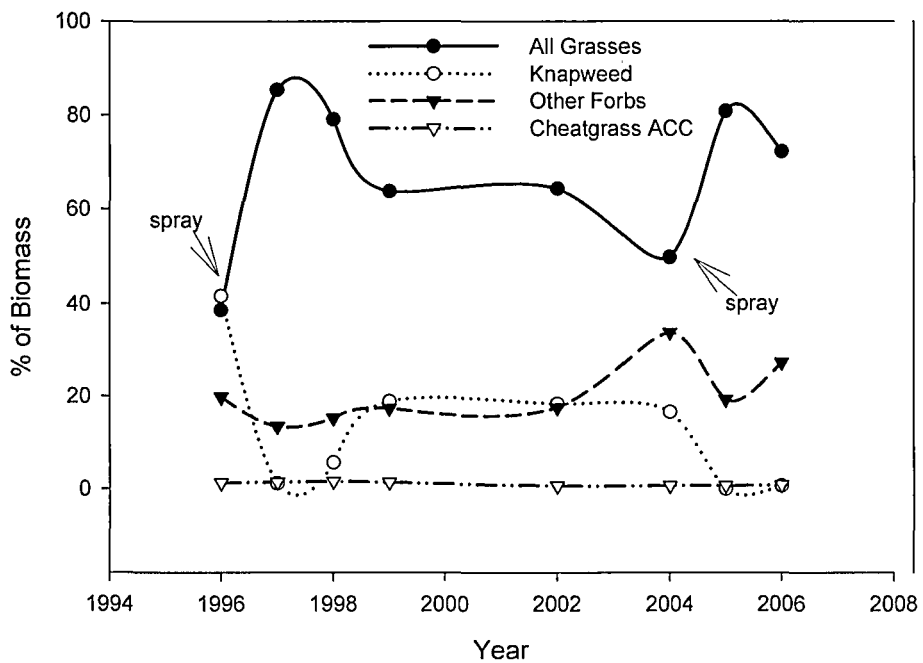

Figure 1. Average percent biomass (of total biomass) for grasses, spotted knapweed, other forbs for eight double sampled test plots sprayed in fall of 1996 and fall 2004; as well as absolute canopy cover of cheatgrass.

Permanent plot diversity

The Sawmill plant community is species rich (Table 3). Average species richness differs between plots and between years ($p<.001$, two-way analysis of variance). For the ten permanent full community plots there was an average decline of approximately five species from the pre-spray 1995 richness to the 1998 sample (two growing seasons post-spray with Tordon) (Table 3 and Figure 2d). This initial average decline in species richness may be attributable to the Tordon treatment. The picloram residual in the soil drops below phytotoxic levels by the third year post-spray after a Tordon application rate of 1 pt/ac. Total species richness had returned to pre-spray level of 78 species by 1999 (3 growing seasons post spray). However, average and total species richness was even lower in 2002 (six growing seasons post-spray) and continued to decline through 2004 (eight growing seasons post spray). These 2000-2004 declines in average and total richness are attributable to the extreme droughty conditions which began in the fall of 1999 and have continued through 2006 (Table 3 and Figure 2a). Average species richness declined by about two species in the year (r+1) following the fall 2004 Transline re-spray treatment, but measured total species richness was slightly higher in the first growing season after re-spraying Transline. Both the measured average and total species richness were increasing in the second growing season (r+2) after the re-spray with Transline.

Species richness in 2002 and 2004 on the not-weedy, not-sprayed before fall 2004, grassland habitat type check plots was also less than the averages for the full community plots in 1995, and declined sharply in the interval 2002 to 2004 under cumulative drought stress (Table 3). No further decline was measured in these two plots after the fall 2004 helicopter treatment with Transline.

The Shannon-Weaver diversity index differed between plots and years ($p<.001$, two-way analysis of variance). This diversity index declined in the years after both spray treatments (Table 4 and Figure 2b). However the decline in the first growing season (r+1) after the fall 2004 Transline treatment was very slight, and there was a sharp diversity increase in the second growing season (r+2) after the Transline treatment. The initial and more protracted post Tordon spray decline in Shannon-Weaver diversity continued through the droughty years and declined very strongly from 2002 (six growing seasons post-spray) to 2004 (eight growing seasons post-spray). In 2002 and 2004 the not-weedy, no-spray check plots (Table 4), and the plots that had been sprayed in 1996, had Shannon-Weaver diversity values suggesting that the cumulative drought was one of the factors controlling diversity since 2000. There would have been no picloram residual this long after the fall 1996 Tordon treatment.

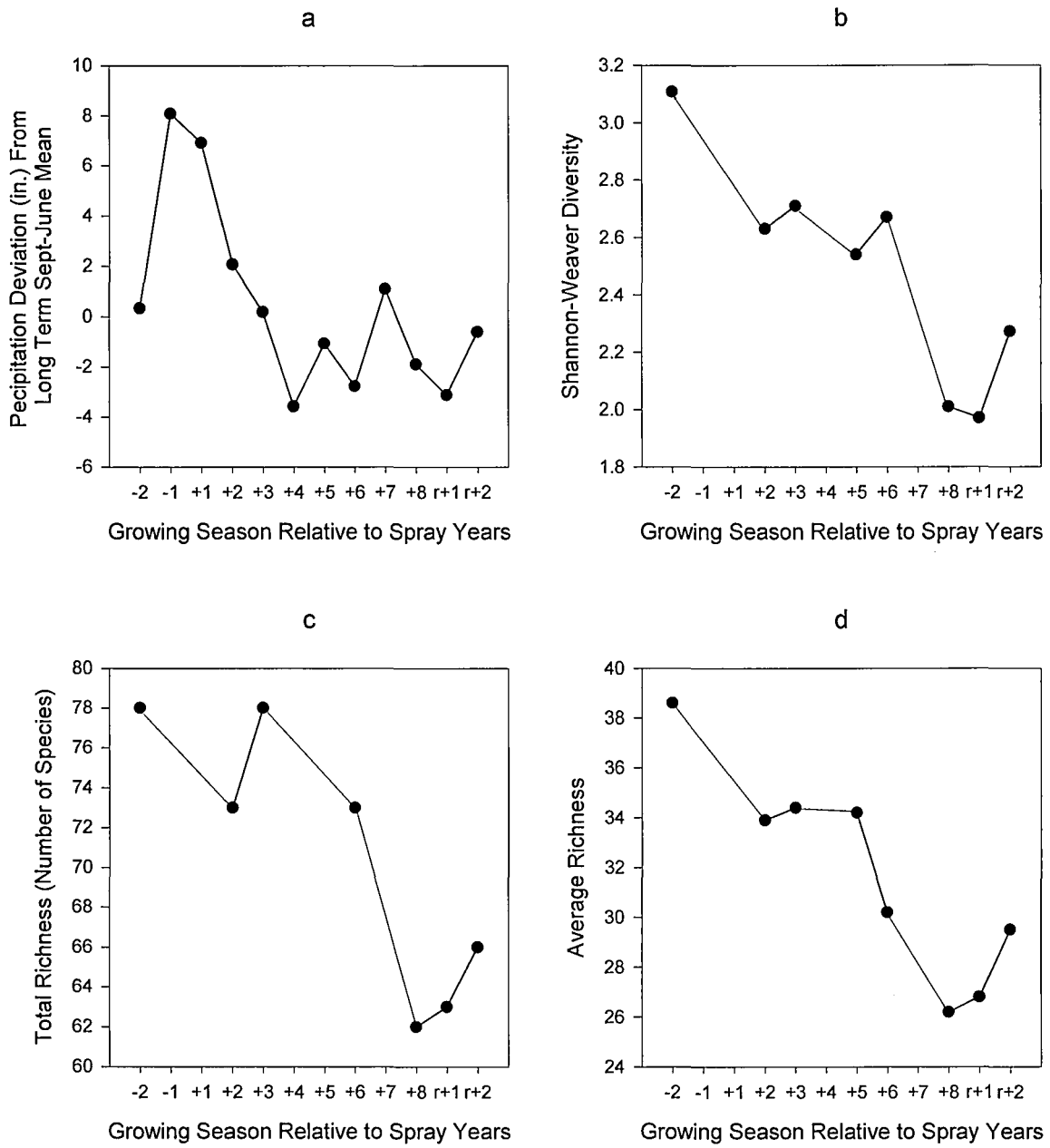

Figure 2. Precipitation deviation from long term (1911-1997) Sept-June mean total and diversity measurements compared to growing season relative to spray years (r = fall 2004 respray).

Table 3. Species richness in Sawmill permanent full community test plots.

		Growing Season Relative to Fall Herbicide Treatments (r = fall 2004 re-spray) & Calendar Year											
HABITAT TYPE	PLOT	-2 1995	-1 1996	+1 1997	+2 1998	+3 1999	+4 2000	+5 2001	+6 2002	+7 2003	+8 2004	r+1 2005	r+2 2006
ARTTRI/FESSCA	904	48			51	49			40		36	45	41
ARTTRI/FESSCA	905	42			43	43			38		35	35	32
	Mean	45			47	46			39		35.5	40.0	36.5
	Total	54			53	54			48		45	49	45
FESIDA/AGRSPI	902	35			25	24		26	28		26	21	25
FESIDA/AGRSPI	903	45			37	35		38	36		33	26	34
FESIDA/AGRSPI	906	40			34	34		35	37		32	30	34
FESIDA/AGRSPI	911	39			31	35		35	16		29	25	27
FESIDA/AGRSPI	916	27			27	24		26	22		25	22	22
FESIDA/AGRSPI	922	33[†]			24	30		27	30		23	23	32
	Mean	36.5			29.7	30.3		31.2	28.2		28.0	24.5	29.0
	Total	72			61	60		57	58		49	45	53
FESSCA/FESIDA	909	43			37	35		37	33		30	25	28
FESSCA/FESIDA	910	34			30	35		30	22		23	16	20
	Mean	38.5			33.5	35.0		33.5	27.5		26.5	20.5	24.0
	Total	47			41	45		43	36		36	28	32
All Ten Plots	Mean	38.6			33.9	34.4		34.2[§]	30.2		29.2	26.8	29.5
All Ten Plots	Total	78			73	78			73		62	63	66
Not Weedy No-Spray[∫] Checks													
FESIDA/AGRSPI	913								36		22	26	22
FESSCA/FESIDA	914								25		15	17	22
Precipitation* (in.)	10.8[ψ]	11.2	18.9	17.8	12.9	11.0	7.3	9.8	8.1	11.9	8.9	7.7	10.2
Deviation from Long Term		+0.3	+8.1	+6.9	+2.1	+0.2	-3.6	-1.1	-2.8	+1.1	-1.9	-3.1	-0.6

[§]Estimated marginal mean with correction for missing values

[∫] Not Weedy No-Spray Check plots were not sprayed until the fall 2004 helicopter Transline application, no richness data before 2002

*Precipitation is summed for Sept. through June at Stevensville Ranger Station

[ψ]87 year (1911-1997) average for Sept. through June at Stevensville Ranger Station

[†]922 was first sampled in 1996 before spraying, precipitation leading to that growing season was 18.9 in.

Table 4. Shannon-Weaver Diversity (log10) in Sawmill permanent full community test plots.

		Growing Season Relative to Fall Herbicide Treatments (r = fall 2004 re-spray) & Calendar Year											
HABITAT TYPE	PLOT	-2 1995	-1 1996	+1 1997	+2 1998	+3 1999	+4 2000	+5 2001	+6 2002	+7 2003	+8 2004	r+1 2005	r+2 2006
ARTTRI/FESSCA	904	3.42			3.16	3.27			2.87		2.23	2.34	2.24
ARTTRI/FESSCA	905	3.02			2.91	3.00			3.02		2.00	2.13	2.53
	Mean	3.22			3.03	3.14			2.94		2.12	2.24	2.39
FESIDA/AGRSPI	902	3.11			2.38	2.43		2.16	2.45		2.08	1.87	2.32
FESIDA/AGRSPI	903	3.12			2.61	2.74		2.79	2.68		2.17	1.91	2.03
FESIDA/AGRSPI	906	3.16			2.65	2.85		2.69	3.00		1.92	2.26	2.71
FESIDA/AGRSPI	911	3.18			2.40	2.45		2.18	2.25		1.79	1.60	2.14
FESIDA/AGRSPI	916	2.85			2.52	2.45		2.45	2.60		1.99	1.90	2.29
FESIDA/AGRSPI	922	2.76[†]			2.42	2.53		2.57	2.61		2.02	2.14	2.17
	Mean	3.03			2.50	2.58		2.48	2.60		1.99	1.95	2.28
FESSCA/FESIDA	909	3.32			2.77	2.68		2.76	2.82		2.15	2.05	2.51
FESSCA/FESIDA	910	3.11			2.46	2.66		2.26	2.45		1.73	1.49	1.79
	Mean	3.22			2.61	2.67		2.51	2.64		1.94	1.77	2.15
All Ten Plots	Mean	3.11			2.63	2.71		2.54[§]	2.67		2.01	1.97	2.27
Not Weedy No-Spray[∫] Checks													
FESIDA/AGRSPI	913								2.57		1.79	1.78	1.96
FESSCA/FESIDA	914								2.70		1.67	1.61	1.93
Precipitation* (in.)	10.8[ψ]	11.2	18.9	17.8	12.9	11.0	7.3	9.8	8.1	11.9	8.9	7.7	10.2
Deviation from Long Term		+0.3	+8.1	+6.9	+2.1	+0.2	-3.6	-1.1	-2.8	+1.1	-1.9	-3.1	-0.6

[§]Estimated marginal mean with correction for missing values

[∫] Not Weedy No-Spray Check plots were not sprayed until the fall 2004 helicopter Transline application, no richness data before 2002

*Precipitation is summed for Sept. through June at Stevensville Ranger Station

[ψ]87 year (1911-1997) average for Sept. through June at Stevensville Ranger Station

[†]922 was first sampled in 1996 before spraying, precipitation leading to that growing season was 18.9 in.

Test plots similarity to potential natural community

Plot 902 is enclosed to prevent elk grazing. It was not burned. Spraying with Tordon in fall 1996 moved it (+2) towards the potential natural vegetation habitat type definition for Idaho fescue/bluebunch wheatgrass (Figure 3). Little additional progress was not evident after 1998 (+2). Regression occurred by 2004 (+8). Then the second spray treatment in fall 2004 using Transline improve (r+1) similarity to the habitat type definition but this was followed by marked regression (r+2) back towards the unsprayed state.

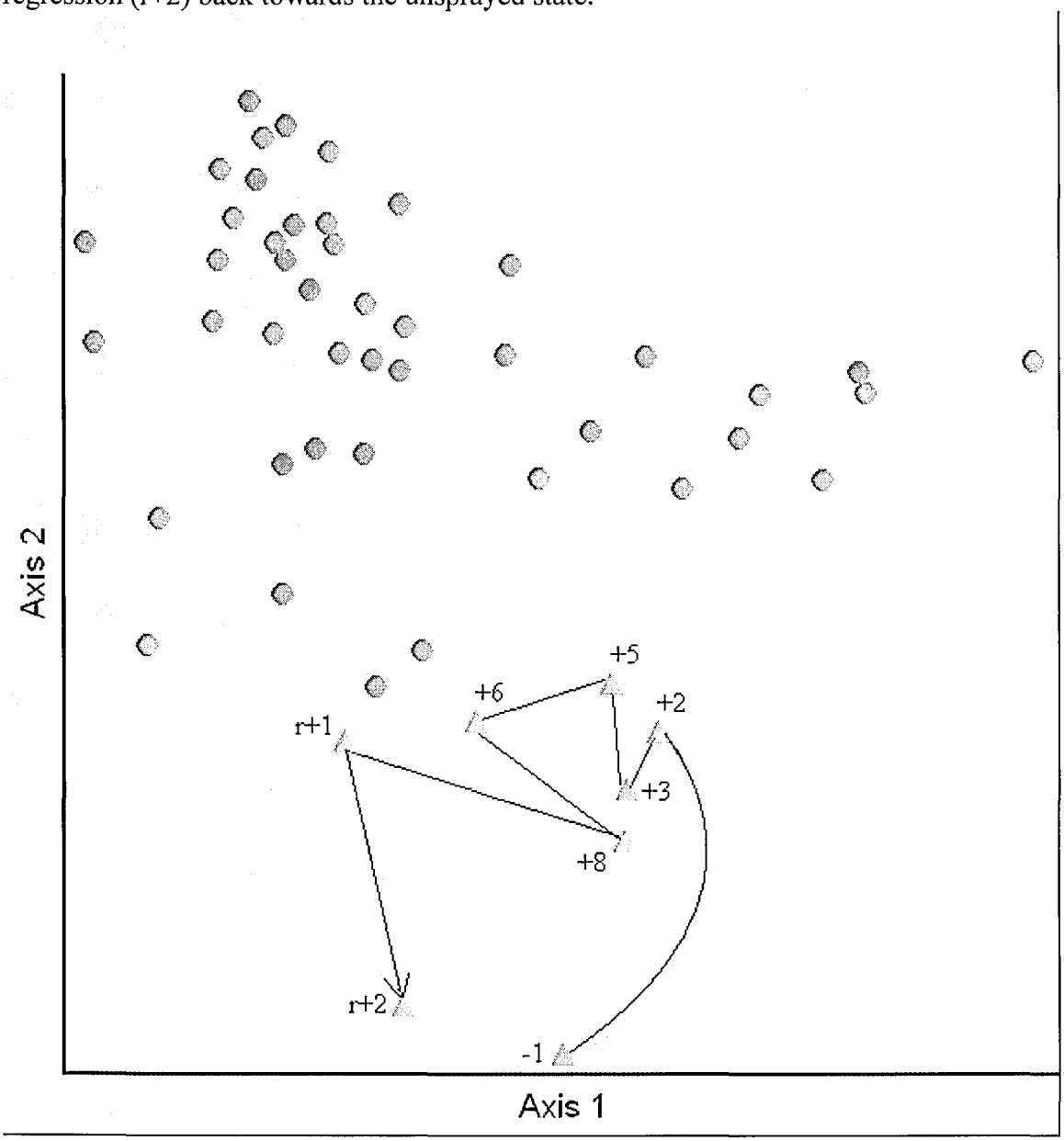

Figure 3. Floristic trajectory of Sawmill FESIDA/AGRSPI plot 902 (*) starting at the –1 growing season (1995) before first spraying Tordon in fall 1996, then +2 (1998), +3 (1999), +5 (2001), +6 (2002), +8 (2004) growing seasons after first spraying, then r+1(2005) and r+2 (2006) growing seasons after re-spraying with Transline in fall 2004 relative to the Mueggler & Stewart h.t. definition plots (*) (2 Dimensional Stress 14.7).

Plot 903 is open to elk grazing. Although it initially moved (+2) towards the habitat type definition following spraying, it retrogressed to its unsprayed state by 2002 (+6) (Figure 4). It was burned in fall 2001. A relatively large shift back towards the habitat type definition occurred by 2004 (+8), but the application of Transline in the fall of 2004 did not lead to any further improvements in similarity of Sawmill plot 903 to the Mueggler and Stewart definition plots for the Idaho fescue/bluebunch wheatgrass habitat type.

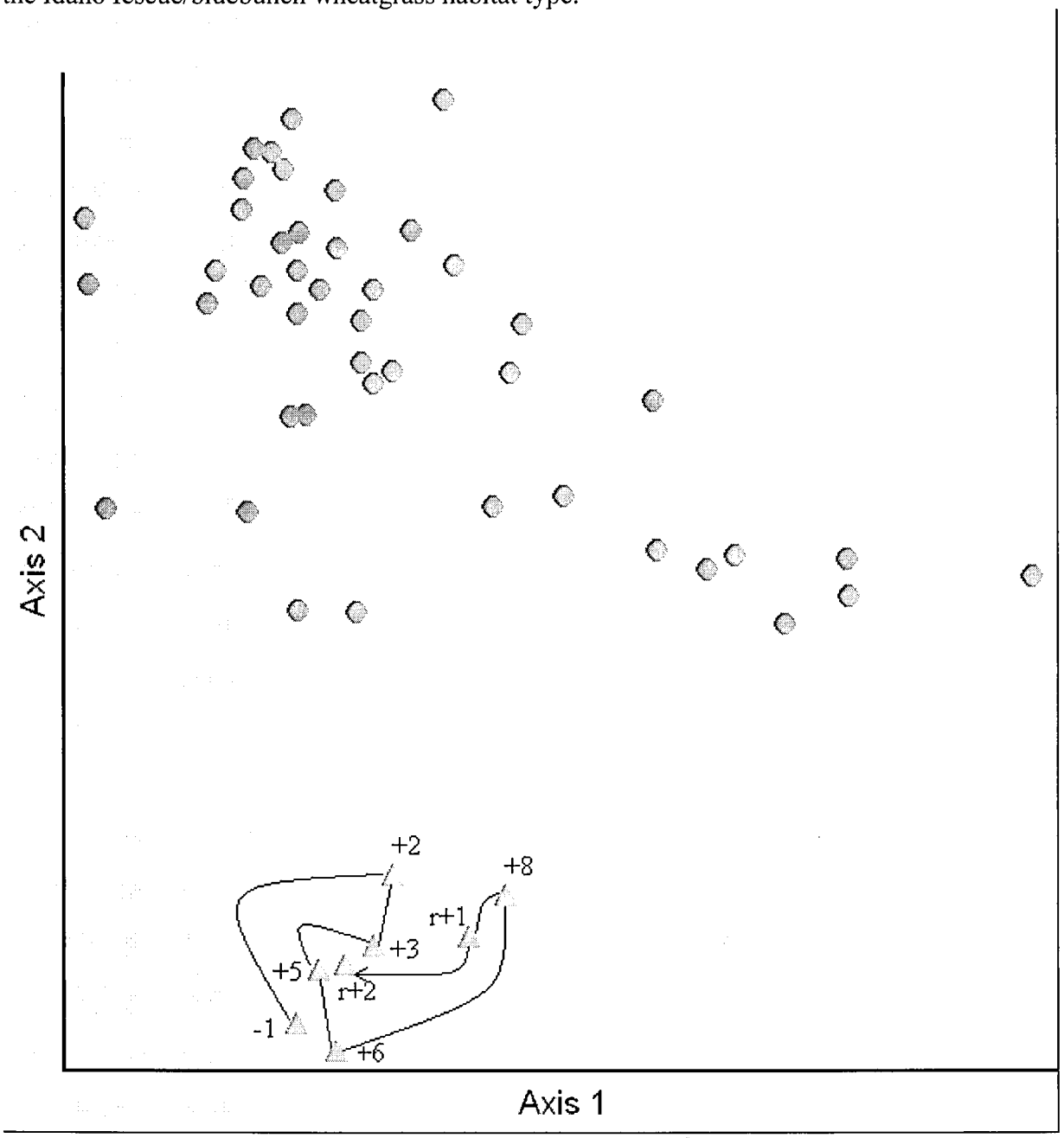

Figure 4. Floristic trajectory of Sawmill FESIDA/AGRSPI plot 903 (*) starting at the –1 growing season (1995) before first spraying Tordon in fall 1996, then +2 (1998), +3 (1999), +5 (2001), +6 (2002), +8 (2004) growing seasons after first spraying, then r+1(2005) and r+2 (2006) growing seasons after re-spraying with Transline in fall 2004 relative to the Mueggler & Stewart h.t. definition plots (*) (2 Dimensional Stress 12.2).

Plot 906 is open to elk grazing. After a large initial (+2) post-spray movement to the Mueggler and Stewart plots defining the Idaho fescue/bluebunch wheatgrass potential natural community, plot 906 entered a six year period of retrogression (Figure 5). The plot had been burned in fall 2001. By 2002 (+6) its composition was similar to that at the start. There was a second improvement (r+1) in similarity to the habitat type definition following the fall 2004 Transline application, but this shift was not of the same magnitude as the initial spray improvement.

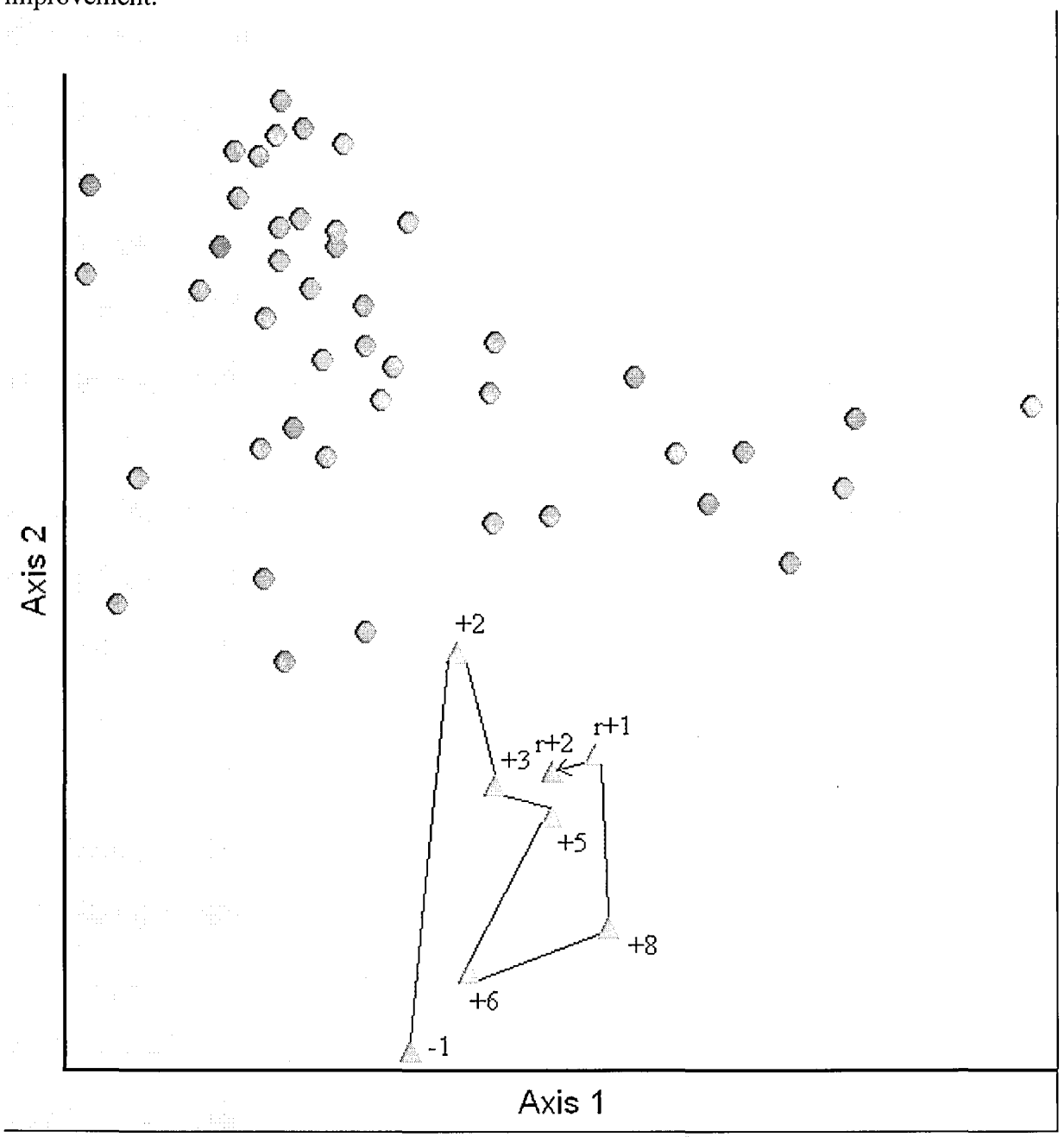

Figure 5. Floristic trajectory of Sawmill FESIDA/AGRSPI plot 906 (*) starting at the –1 growing season (1995) before first spraying Tordon in fall 1996, then +2 (1998), +3 (1999), +5 (2001), +6 (2002), +8 (2004) growing seasons after first spraying, then r+1(2005) and r+2 (2006) growing seasons after re-spraying with Transline in fall 2004 relative to the Mueggler & Stewart h.t. definition plots (†) (2 Dimensional Stress 13.3).

Plot 911 is open to elk grazing. It (+2) underwent a large shift in overall composition and moved within the Idaho fescue/bluebunch wheatgrass habitat type definition following the fall 1996 Tordon spraying (Figure 6). Then plot 911 steadily regressed through 2002 (+6) to a composition nearly similar to its pre-spray state. This plot was burned in fall 2001. By 2004 (+8) it had move strongly back towards the potential natural community. A small improvement (r+1) followed the fall 2004 Transline application, then a small retreat in 2005 (r+2).

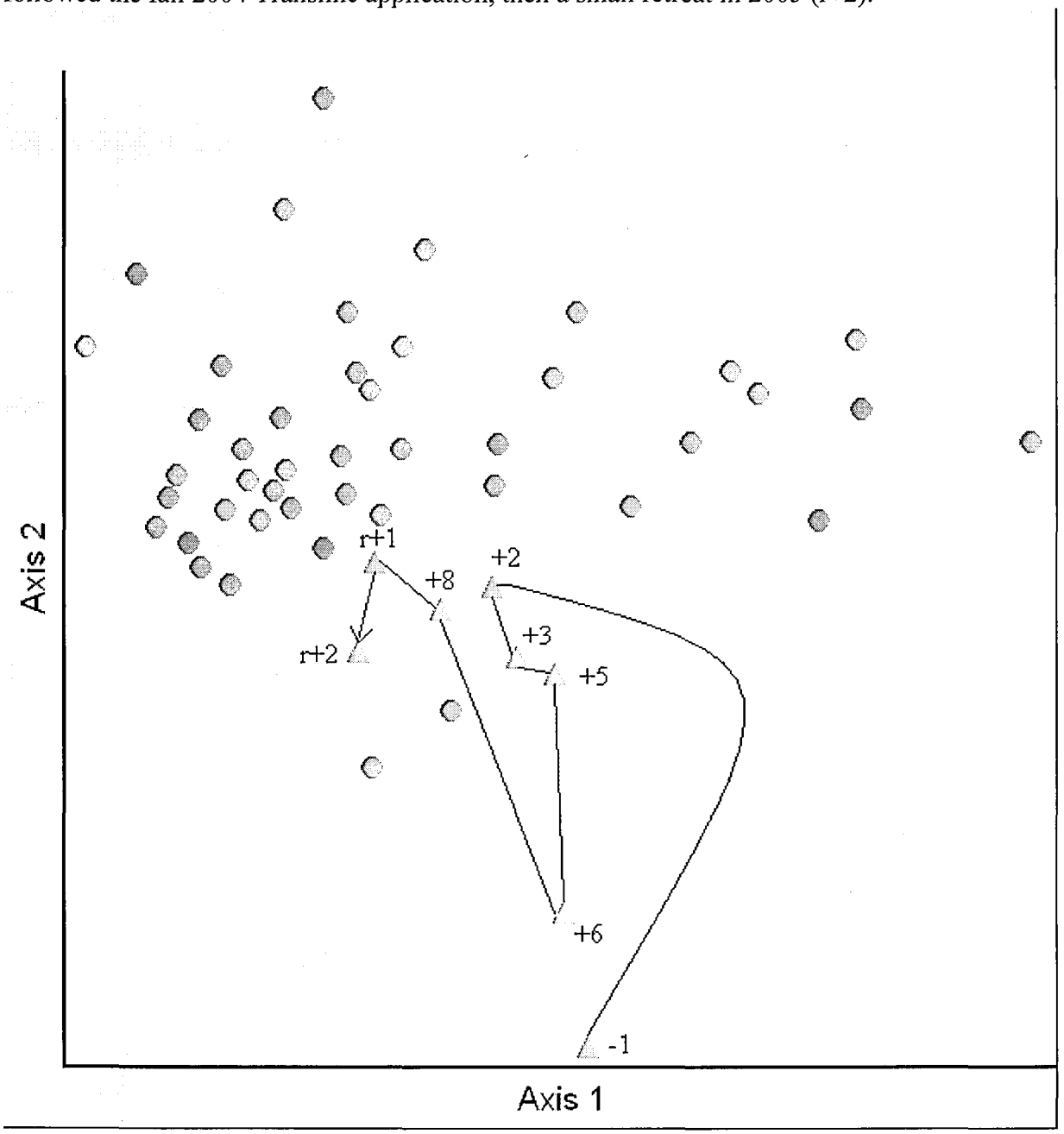

Figure 6. Floristic trajectory of Sawmill FESIDA/AGRSPI plot 911 (*) starting at the –1 growing season (1995) before first spraying Tordon in fall 1996, then +2 (1998), +3 (1999), +5 (2001), +6 (2002), +8 (2004) growing seasons after first spraying, then r+1(2005) and r+2 (2006) growing seasons after re-spraying with Transline in fall 2004 relative to the Mueggler & Stewart h.t. definition plots (*) (2 Dimensional Stress 15.7).

Plot 916 is enclosed to prevent elk grazing. It was not burned. Following Tordon in fall 1996 spraying it initially (+2) moved towards the Idaho fescue/bluebunch wheatgrass potential natural community (Figure 7). However after 1998 plot 916 began to move slowly back towards its pre-spray species composition until 2004 (+8). Then the trajectory appeared rebound (+8) towards of the potential natural community, but in the two years following the fall 1994 Transline treatment plot 916 entered a strong retrogressive phase ending near the initial 1995 state.

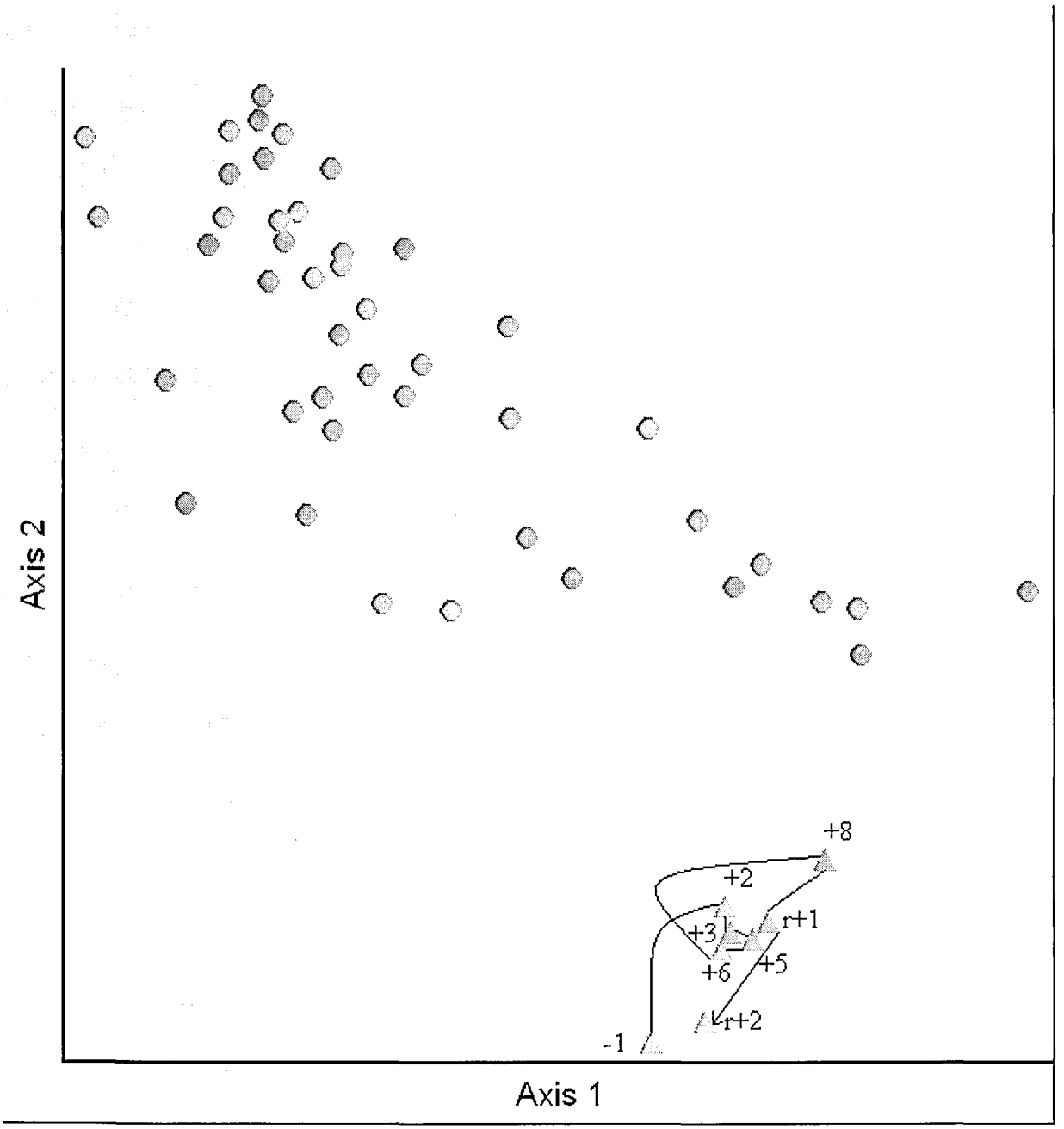

Figure 7. Floristic trajectory of Sawmill FESIDA/AGRSPI plot 916 (*) starting at the –1 growing season (1995) before first spraying Tordon in fall 1996, then +2 (1998), +3 (1999), +5 (2001), +6 (2002), +8 (2004) growing seasons after first spraying, then r+1(2005) and r+2 (2006) growing seasons after re-spraying with Transline in fall 2004 relative to the Mueggler & Stewart h.t. definition plots (*) (2 Dimensional Stress 12.3).

Plot 922 is open to elk grazing. Following an initial (+2) post 1996 Tordon spray move towards the Idaho fescue/bluebunch wheatgrass habitat type definition plot 922 began a steady regression after that continue until 2002 (+6) (Figure 8). This plot was burned in fall 2001. As of 2002 the composition was more dissimilar than it had been at the 1996 pre-spray state. From 2002 to 2004 (+8) plot 922 improved in similarity to the potential natural vegetation as did four of the other five Idaho fescue/bluebunch wheatgrass plots. The plot similarity to the potential natural vegetation increased further (r+1) after the fall 2004 Transline treatment. Then in 2006 (r+2) it reverted to a state very similar to the 1995 pre-spray composition.

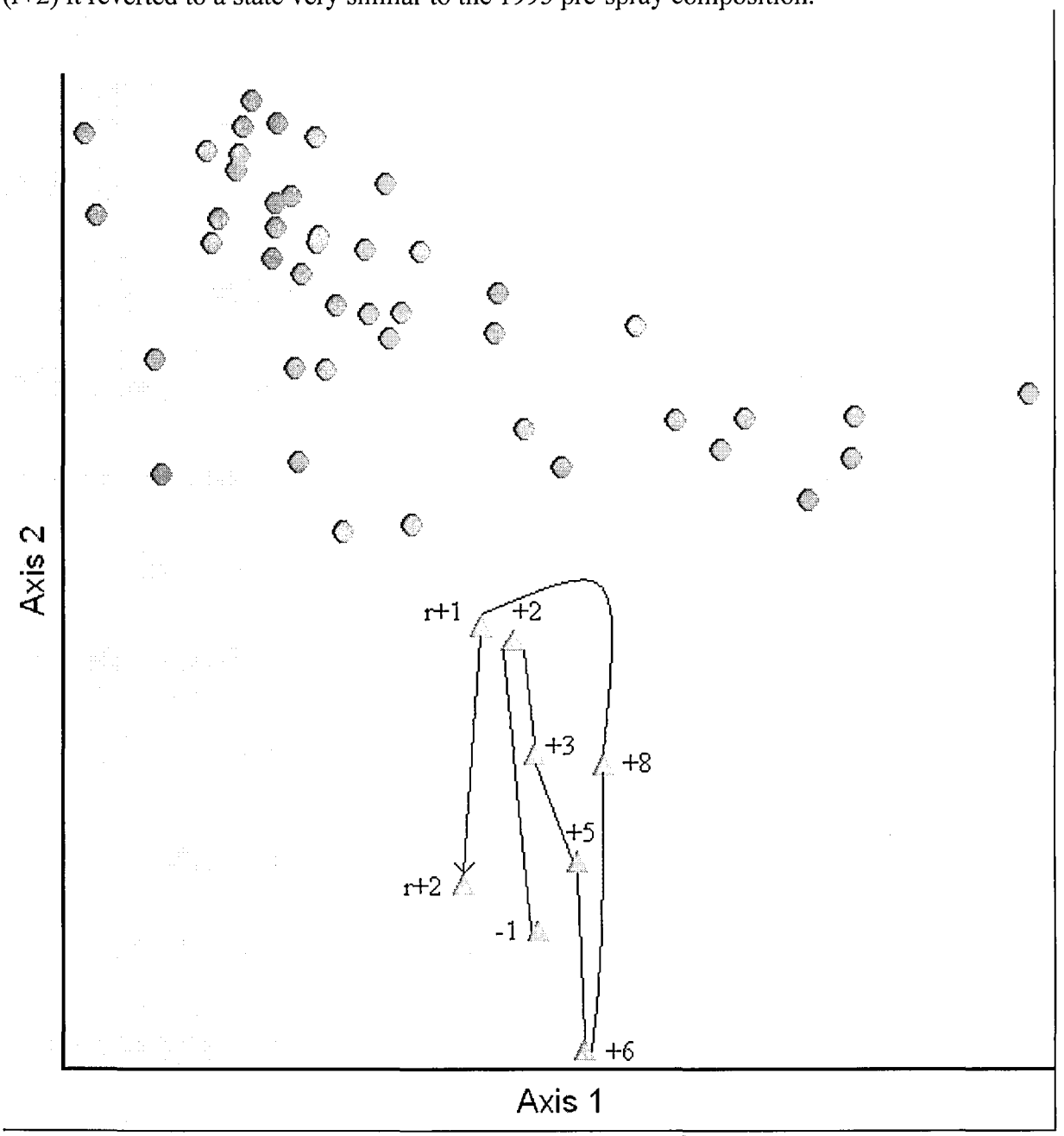

Figure 8. Floristic trajectory of Sawmill FESIDA/AGRSPI plot 922 (*) starting at the –1 growing season (1995) before first spraying Tordon in fall 1996, then +2 (1998), +3 (1999), +5 (2001), +6 (2002), +8 (2004) growing seasons after first spraying, then r+1(2005) and r+2 (2006) growing seasons after re-spraying with Transline in fall 2004 relative to the Mueggler & Stewart h.t. definition plots (*) (2 Dimensional Stress 13.2).

The rough fescue/Idaho fescue Plot 909 is open to elk grazing. Although it had moved towards the potential natural community following spraying (+2) it was still quite dissimilar from the habitat type definition (Figure 9). Following the initial move (+2) of plot 909 composition towards the potential natural community, it has been in retrogression from1999 (+3) through 2002 (+6). It was burned in fall 2001. The fall 2004 Transline treatment again drove the species composition (r+1) towards the rough fescue/Idaho fescue habitat type definition plots. However in 2006 (r+2) plot 909 fully reverted for a second time

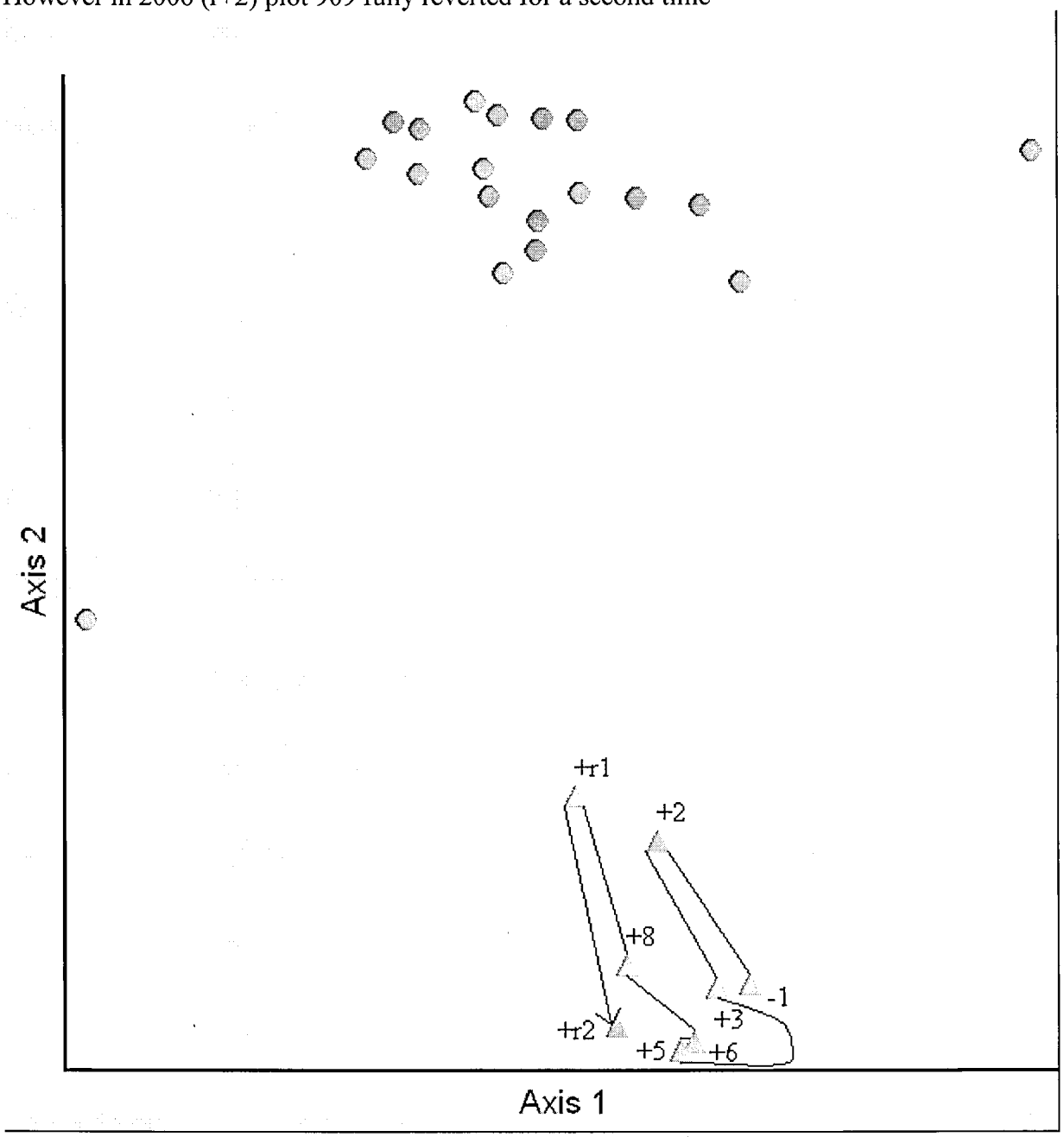

Figure 9. Floristic trajectory of Sawmill FESSCA/FESIDA plot 909 (*) starting at the –1 growing season (1995) before first spraying Tordon in fall 1996, then +2 (1998), +3 (1999), +5 (2001), +6 (2002), +8 (2004) growing seasons after first spraying, then r+1(2005) and r+2 (2006) growing seasons after re-spraying with Transline in fall 2004 relative to the Mueggler & Stewart h.t. definition plots (*) (2 Dimensional Stress 9.1).

Plot 910 is enclosed to prevent elk grazing. This plot was burned in the fall of 2001. Both spray treatments moved the species composition of this rough fescue/Idaho fescue habitat type plot toward the potential natural community (Figure 10). That overall post-spray trajectory was towards the potential natural community with only minor retrogressions in 2002 (+6) and 2004 (+8).

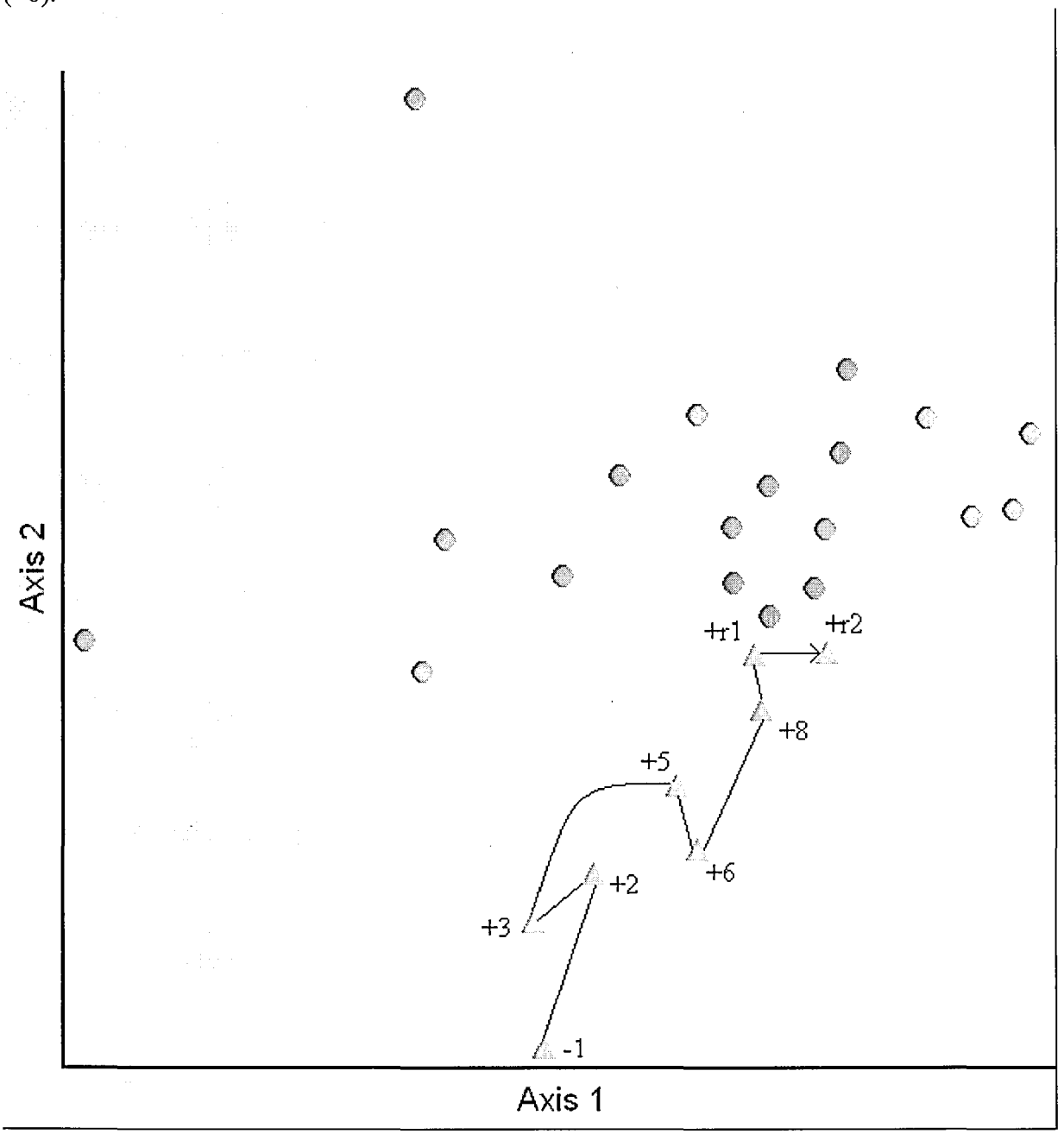

Figure 10. Floristic trajectory of Sawmill FESSCA/FESIDA plot 910 (◇) starting at the –1 growing season (1995) before first spraying Tordon in fall 1996, then +2 (1998), +3 (1999), +5 (2001), +6 (2002), +8 (2004) growing seasons after first spraying, then r+1(2005) and r+2 (2006) growing seasons after re-spraying with Transline in fall 2004 relative to the Mueggler & Stewart h.t. definition plots (◆) (2 Dimensional Stress 14.0).

Plot 904 is enclosed to prevent elk grazing. It was not burned in fall 2001 and we did not have 2001 data for this plot. This big sagebrush/rough fescue habitat type plot has made overall progress towards the potential natural community (Figure 11).

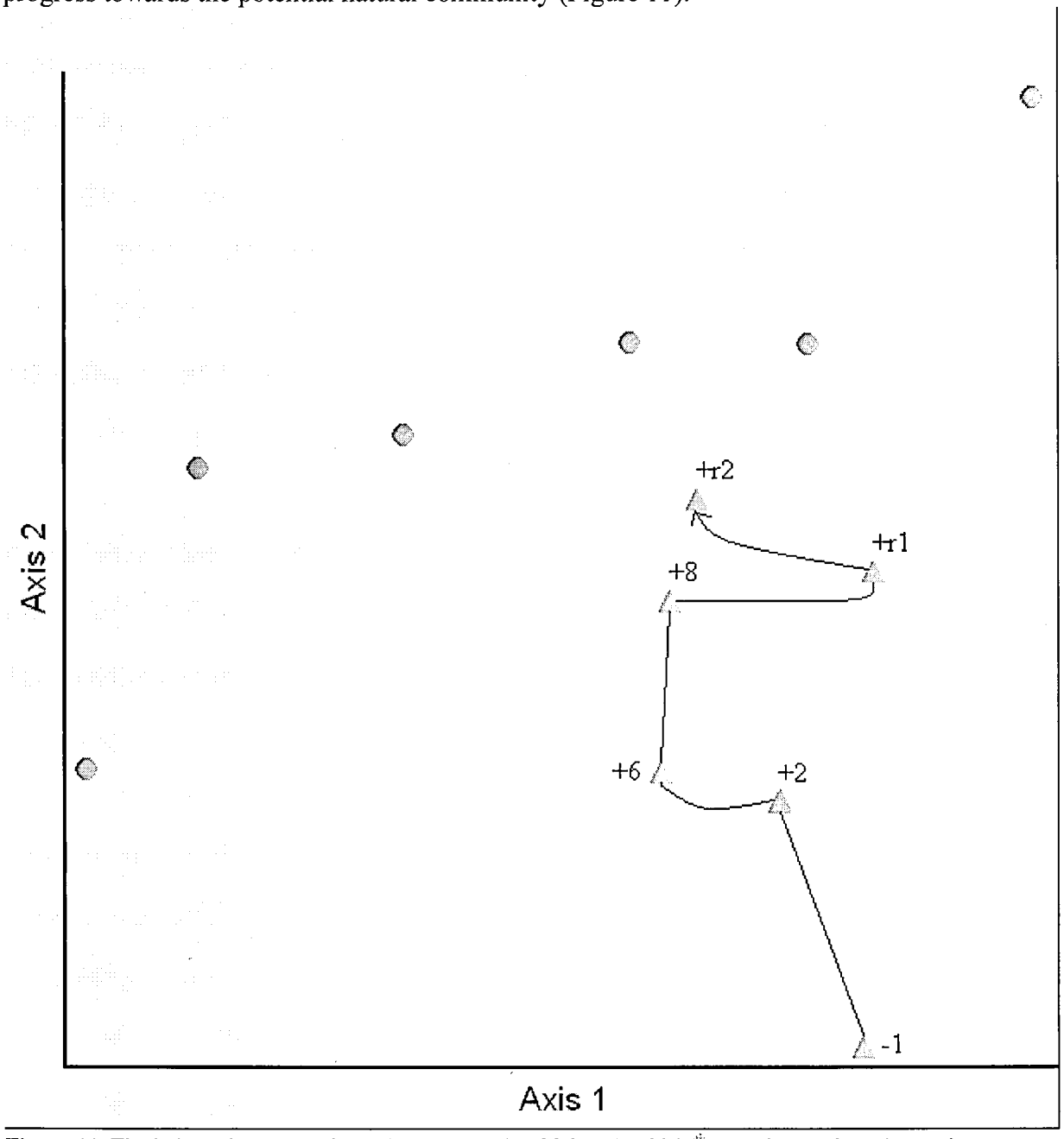

Figure 11. Floristic trajectory of Sawmill ARTTRI/FESSCA plot 904 (*) starting at the –1 growing season (1995) before first spraying Tordon in fall 1996, then +2 (1998), +6 (2002), +8 (2004) growing seasons after first spraying, then r+1(2005) and r+2 (2006) growing seasons after re-spraying with Transline in fall 2004 relative to the Mueggler & Stewart h.t. definition plots (*) (2 Dimensional Stress 9.9).

Plot 905 is open to elk grazing. It was not burned in fall 2001 and we did not have 2001 data for this plot. This big sagebrush/rough fescue habitat type plot made initial progress (+2) toward the potential natural community after the fall 1996 Tordon spraying, regressed somewhat in 1999, then continued on a trajectory towards the habitat type definition (Figure 12). An additional small improvement in similarity (r+1) was measured in the growing season after the fall 2004 Transline application.

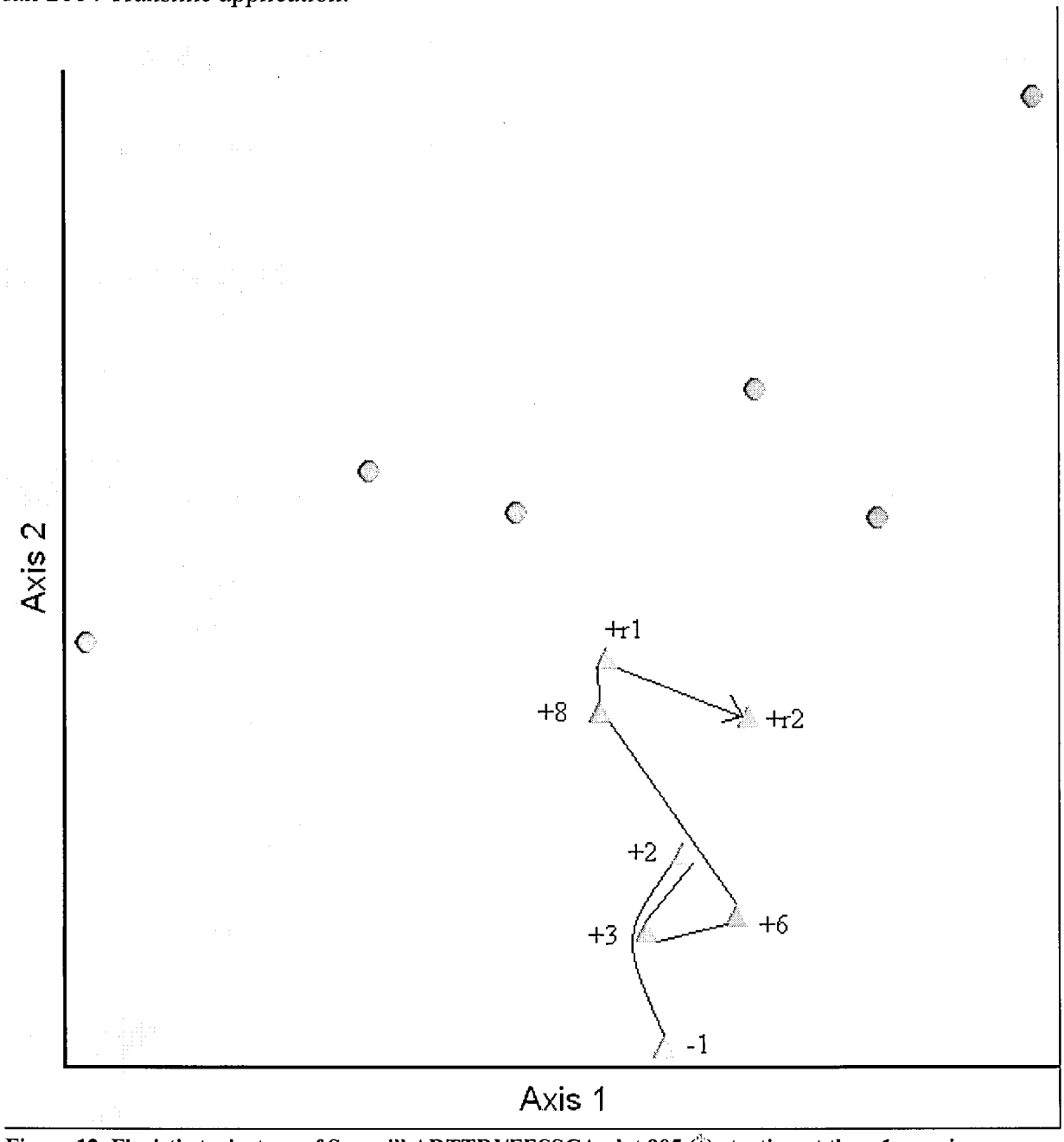

Figure 12. Floristic trajectory of Sawmill ARTTRI/FESSCA plot 905 (*) starting at the –1 growing season (1995) before first spraying Tordon in fall 1996, then +2 (1998), +3 (1999), +6 (2002), +8 (2004) growing seasons after first spraying, then r+1(2005) and r+2 (2006) growing seasons after re-spraying with Transline in fall 2004 relative to the Mueggler & Stewart h.t. definition plots (*) (2 Dimensional Stress 9.6).

At the start of monitoring in 1995 before herbicides were applied all ten permanent full community plots were markedly dissimilar from their respective Mueggler and Stewart (1980) habitat type definition plots. Overall by the second growing season post-spray (1998) the initial Tordon herbicide treatment of the ten permanent full community test plots in fall 1996 had made all ten plots representing the three grassland communities types at Sawmill more similar to the potential natural communities (Figures 3-12).

For the period three years post-spray (1999) through six years (2002) post-spray similarity was little changed in four plots and the initial progression toward the potential natural communities was reversed for six plots. The four plots (902, 916, 910, 904) that were enclosed in fall 1996 to prevent elk overgrazing following the test spraying were the four plots that had little change; while the six plots that were open to elk grazing were the same six that regressed to a composition less similar to the potential natural vegetation. Three of these six open to grazing retrogressed plots were less similar to the potential natural vegetation in 2002 than they were in 1995.

Five of the six grassland habitat type plots that were burned in the fall of 2001 retrogressed from the potential natural community definition plots in the 2002 growing season (+5 to +6). The sixth burned plot (909) was little changed over that interval, as were the two unburned plots (902 and 916). It is typical for burned bunchgrasses to be growth retarded in the first growing season after a burn, particularly if the stand had not burned for some years and there was accumulated litter in the bunch bases. We did not have 2001 data for the two big sagebrush plots and both of these were in the grasslands below the lower road so they were not burned.

Progression towards the potential natural community was evident again in the period from 2002 (+6) to 2004 (+8). Eight of the ten Sawmill plots moved towards their habitat type definition plot groups. One plot (906) was little changed relative to its definition plots and one plot (902) retrogressed.

Community composition in seven of the ten plots moved further toward the habitat type definitions in the 2005 growing season (r+1) after the fall 2004 helicopter Transline application. One plot (904) was little changed relative to the potential natural vegetation. Plot 903 and 916 retrogressed in 2005. In spite of the overall improvement in similarity in the first growing season after the Transline treatment there was overall decrease in similarity from 2005 to 2006 (r+2). Seven of the ten plots retrogressed, although this loss was slight on several of these plots. There was little change in the other three plots.

As of 2006 five of the ten plots had returned to a species composition quite similar to their 1995 pre-spray states, and were again distinctly dissimilar from their respective habitat type definition plots. Most of this retrogression from previous improvement in similarity to the potential natural was a result of marked reversals from 2005 to 2006. Five of the ten plots ended in 2006 with a species composition more similar to their habitat type definition plots. Only one plot, bluebunch wheatgrass/Idaho fescue plot 911, finished definitively within its habitat type definition having improved from an initially strongly dissimilar state.

Extensive grasslands

The responses to spraying the extensive grasslands in fall 1998 with 1 pt/ac Tordon and a second time in fall 2004 with 2/3 pt/ac of Transline were similar to the responses on the test

plots. The extensive grasslands were sampled by using transects and estimating canopy cover of indicator species and life form groups during the period 1998 through 2005. The relative canopy cover data for the original 14 efficacy transects are summarized in Figure 13. You might compare the similarity of Figure 13 and Figure 1.

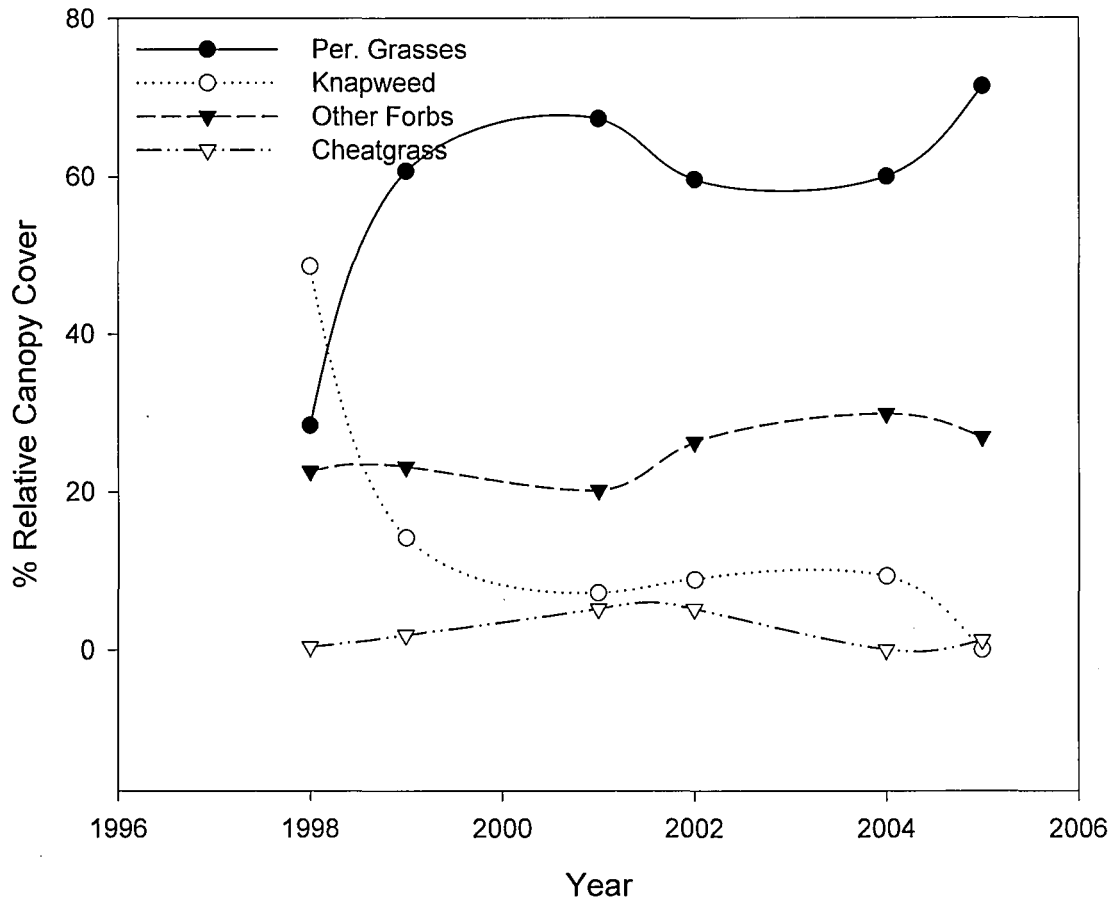

Figure 13. Percent relative canopy cover of four life form groups in the extensive grasslands efficacy/fuel transects following spraying in fall 1998 and fall 2004.

Details of the responses of the extensive grasslands based on the original 14 efficacy transects are summarized in Tables 5 and 6. The fall 2004 Transline treatment did not only greatly reduce the knapweed canopy cover, but it additionally reduced the frequency of occurrence of knapweed to 6% (Table 6). These knapweed occurrences were primarily in the big sagebrush/rough fescue habitat type where the big sagebrush prevented the spray droplets from reaching the spotted knapweed. Frequency of occurrence of other forbs increased greatly in 2004 and 2005, presumably due to seed germination allowed by more favorable May precipitation conditions (3.32 inches in 2004 and 2.94 inches in 2005).

Annual brome species are widespread in the grassland habitat types at the Sawmill RNA, but average canopy cover has remained low throughout the years of monitoring (Table 7). The goatweed plots and the weedy no-spray check plots have had the highest abundances of cheatgrass (Table 8). These previously degraded areas have the lowest abundances of perennial grasses and are susceptible to cheatgrass flushes following spraying or when rainfall amounts and timing correspond with the early spring primary growth period for cheatgrass.

Table 5. Absolute canopy cover response of vegetation (14 original transects) to extensive grassland Tordon spraying in fall 1998, and secondary Transline treatment in fall 2004.

SPECIES OR LIFE FORM	% CANOPY COVER (ABSOLUTE)					
	1998 (PRE-SPRAY)	1999 (1 YR POST)	2001 (3 YRS POST)	2002 (4 YRS POST)	2004 (5 YRS POST)	2005 (1 YR POST SECONDARY)
CENMAC	25.2	3.0	3.6	1.9	3.4	0.2
BROTEC	0.2	0.4	2.6	1.1	0.3	0.5
ATRTRI	0.5	0.8	1.0	0.5	0.5	0.3
AGRSPI	4.3	4.3	10.3	3.2	7	4.9
FESIDA	5.0	3.8	11.9	4.5	7.8	8.5
FESSCA	3.1	2.7	4.9	1.9	4.8	7.8
O. ANN. GRASSES	0.2	not measured	0.1	0.1	< 0.1	1.5
OTHER FORBS	11.7	4.9	10.1	5.6	10.9	10.9
O. PER. GRASSES	2.3	2.0	6.5	3.1	2.3	7.7
OTHER SHRUBS	<0.1	0.0	<0.1	<0.1	< 0.1	0.3
POTREC	<0.1	0.0	0.0	0.0	0	0

Table 6. Frequency of occurrence response of vegetation (14 original transects) to extensive grassland Tordon spraying in fall 1998, and secondary Transline treatment in fall 2004.

SPECIES OR LIFE FORM	% FREQUENCY OF OCCURRENCE					
	1998 (PRE-SPRAY)	1999 (1 YR POST)	2001 (3 YRS POST)	2002 (4 YRS POST)	2004 (5 YRS POST)	2005 (1 YR POST SECONDARY)
CENMAC	91	26	41	51	51	6
BROTEC	19	16	40	29	26	16
ATRTRI	4	4	4	10	0.5	0.3
AGRSPI	63	54	64	57	57	47
FESIDA	94	87	94	84	79	80
FESSCA	41	43	44	50	44	36
O. ANN. GRASSES	99	93	99	74	4	23
OTHER FORBS	26	not measured	20	21	100	91
O. PER. GRASSES	93	89	89	86	53	91
OTHER SHRUBS	1	0	1	1	1	6
POTREC	1	0	0	0	0	0

Table 7. Overall cheatgrass abundance on test plots sprayed in 1996.

1995-2006		MEAN % CC		CONSTANCY	
Habitat Type	# of Plots	BROJAP	BROTEC	BROJAP	BROTEC
FESIDA/AGRSPI	56	0.1	2.8	36%	95%
FESSCA/FESIDA	16	0.1	1.0	44%	69%
ARTTRI/FESSCA	13	<0.1	0.3	7%	69%
All Years-All Plots		0.1	2.1		

Table 8. Cheatgrass response on various monitoring plots and transects after initial Tordon applications in 1996 or 1998,

Percent Canopy Cover	N	95	96	97	98	99	01	02	04	05	06
3 pints/acre on goatweed plots in summer 1995	3**	4.9	17.5	16.5	14.9	2.7		4.9	5.6	14.5	4.0
1 pint/acre on experimental plots in fall 1996	13*	1.2			1.9	1.3	3.1	0.6	0.6	0.7	0.7
1 pint/acre on extensive grasslands in fall 1998	14				0.2	0.4	2.6	1.3	0.3	0.5	
No-spray weedy check plots	2	4.5			1.6	1.8	12.8	4.3	5	8.2	7.3
Non-weedy check plots	3	<0.1		0.0				<0.1	0**	0	<0.1
Percent Frequency of Occurrence											
3 pints/acre on goatweed plots in summer 1995	3**	84	96	99	99	99		83	88	85	100
1 pint/acre on experimental plots in fall 1996	13*	30			36	43	45	25	29	21	30
1 pint/acre on extensive grasslands in fall 1998	14				19	16	40	33	2	16	
No-spray weedy check plots	2	92			88	96	80	98	94	92	100
Non-weedy check plots	3	<1		0				1	0**	0	4

N = number of plots or transects comprising sample
* excludes PINPON h.t. plot 907, which has disturbed surface conditions, N was 8 in 2001, 11 in 2006.
** N = 2 instead of three in 2004 & 2006.

Eradication and containment spraying

Goatweed canopy cover has rebounded to the 1995 pre-spray abundance (Figure 14). Acreage occupied has not been mapped since 1994, but does not appear to have increased beyond the original 4.2 acres, and a few small outlier colonies appeared to have been eradicated through 2005 but some goatweed plant reestablishment was observed in 2006. The main colonies were broadcast sprayed in 1995 (3 pt/ac T22K), and spot sprayed at 2 pt/ac in 1997 and 1998. Chrysolina beetles remain abundant on the Sawmill site and are contributing to the goatweed suppression.

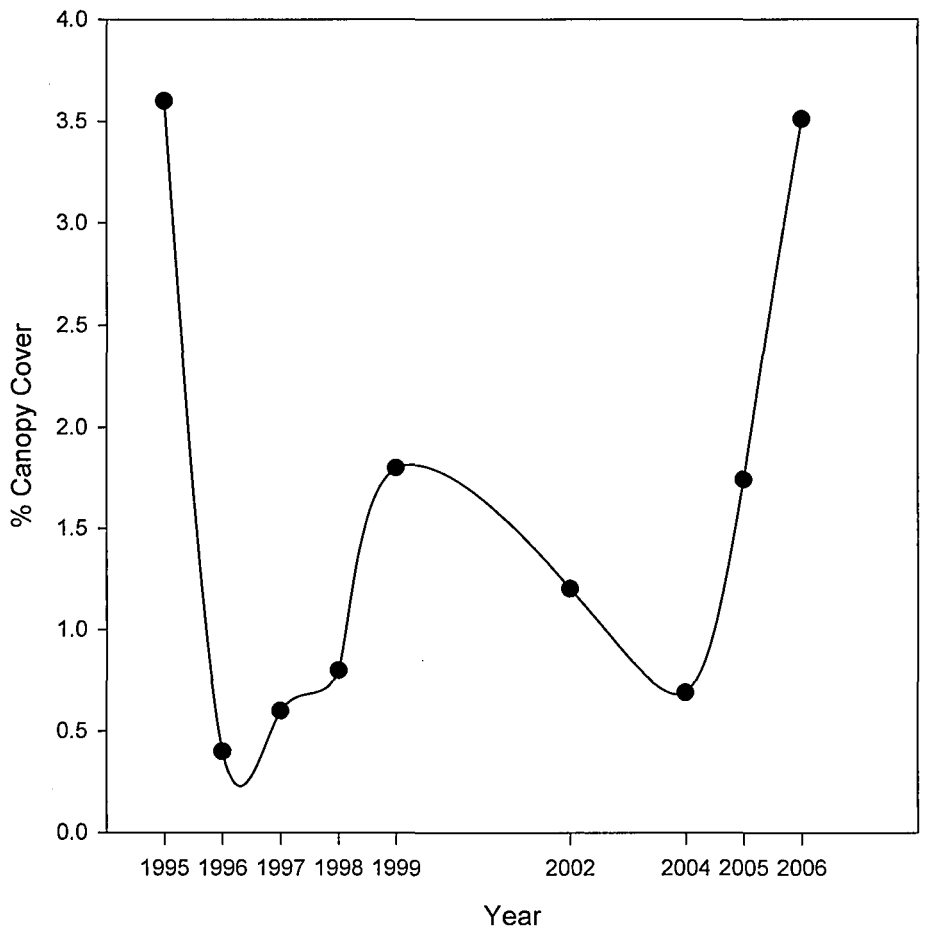

Figure 14. Average goatweed canopy cover on plots #901 and #908.

The single leafy spurge colony has been reduced to a few stems reoccurring after periods of no occurrence (Table 9). A new dalmatian toadflax colony is being found every year or two. Flowering top growth was clipped in 2001 to reduce seed production, but the colonies were not sprayed in 2001. Spraying has reduced the size of individual dalmatian toadflax colonies, and the number of stems, but periodic regrowth or reestablishment from seed continues on all but two of the toadflax colonies. A total of ~0.2 acre was sprayed in both 1995 and 2005.

Table 9. Eradication-observation posts treatments* and target colony response.

Obs. Post	Weed	Original Colony Dia. (ft)	1995	1996	1997	1998	1999	2000	2001	2002	2004	2005	# of Stems Present 2005
1	spurge	40	T3	0	T3	0	0	0	clip	T2D1	0	0	0
2	toadflax	25	T3	0	T3	0	0	T3	clip	T2D1	P12M	P12M	6
3	toadflax	12	T3	0	T3	0	0	0	0	0	0	0	0
4	toadflax	4	T3	0	0	0	0	T3	clip	T2D1	P12M	P12M	12
5	toadflax	35	T3	T3	T3	0	0	T3	clip	T2D1	P12M	P12M	70
6	toadflax	11	T3	0	T3	0	0	0	0	0	0	0	0
7	toadflax	22		T3	0	0	0	T3	clip	T2D1	P12M	P12M	20
8	toadflax	30			T3	0	0	T3	clip	T2D1	P12M	P12M	16
9	toadflax	20					T3	0	0	0	P12M	P12M	7
10	toadflax	5						T3	clip	T2D1	?	P12M	110
11	toadflax	3† x 5							clip	T2D1	P12M	P12M	11
12	toadflax	6								T2D1	P12M	P12M	200+

Dia. refers to ~ diameter size (feet) of initial colony
0 indicates that no top re-growth was observed
*T3 = 3 qt/ac Tordon; T2D1 = 2 qt/ac Tordon + 1 qt/ac 2,4-D; clip = removed flower/seed heads; P1M2 = 12 oz/ac Plateau + 1 qt/ac Methylated Seed Oil
† three ~5 foot diameter clusters

Forest understory

Spotted knapweed abundance in the forested ravines has not changed since the understory baseline was established in 1999 before the thinning and burning treatments were employed to restore a more open forest canopy structure (Table 10). The adjoining extensive grasslands had been sprayed in fall 1998 to reduce potential for influx of seeds to the more open forest canopy and disturbed microsites created by cutting and burning treatments in these ravines. Preexisting knapweed clusters in the forest were spot sprayed in summer 1999. Transline was helicopter sprayed over the entire forest canopy and its opening in fall 2004 to retard any knapweed increase following the broadcast burn in April 2004. During the entire measurement period knapweed canopy cover stayed at ~0.2% and frequency of occurrence at ~5%. The total number of infested plots had little change with a few plots having sustained infestations while the knapweed was transient in other plots.

Table 10. Knapweed in 45 forest understory plots.

Year	Activity	% Canopy Cover	% Frequency of Occurrence†	Number of Infested Plots
1999	Sample Baseline (n 45)	0.17	5.0	6
	Thinning			
	Spot Spray			
	Pile Burn			
2003	Sample Response	0.15	5.6	7
2004	Broadcast Burn April			
	Sample Response	0.20	5.0	6
	Helicopter Spray Fall			
2005	Sample Response	0.16	4.4	6

†based on 160 microplots.

The overall forest understory community was only slightly changed by the forest management actions (Table 11, Figures 15, 16, 17). The effect size change from the 1999 baseline compared to the two post treatment years, although statistically significant, was less than 0.02, a rather small shift in community composition. An effect size of 0.3 would be an ecologically large shift for a bunchgrass community. There was no pre versus post Transline (2004 vs. 2005) shift. The slight compositional change from pre-treatment 1999 to post-treatment years 2004 and 2005 is only apparent in the 2 versus 3 axis of the ordination (Figure 17).

Table 11. Comparison of overall species composition of 45 forest understory plots by Multi Response Permutation Procedure.

Years	Effect Size (A)	p.
1999 vs. 2004	.014	.002
1999 vs. 2005	.016	<.001
2004 vs. 2005	-.004	.990

There were as many total species in the forest understory in 2005 as in 1999, and average species richness did not change between the three years of measurement (Table 12). There was a significant decline in Shannon-Weaver diversity in the post treatment years compared to the 1999 baseline year, but the Transline treatment did not significantly affect the abundance weighted diversity.

Table 12. Diversity in 45 forest understory plots.

	Species Richness		Shannon-Weaver
Year	Total	Average*	Diversity*
1999 (baseline)	94	13.5 a	1.962 a
2004 (after burn, before spray)	82	13.5 a	1.633 b
2005 (after Transline spray)	95	14.4 a	1.582 b

*Means followed by the same letter do not differ significantly (p>0.05, paired t test).

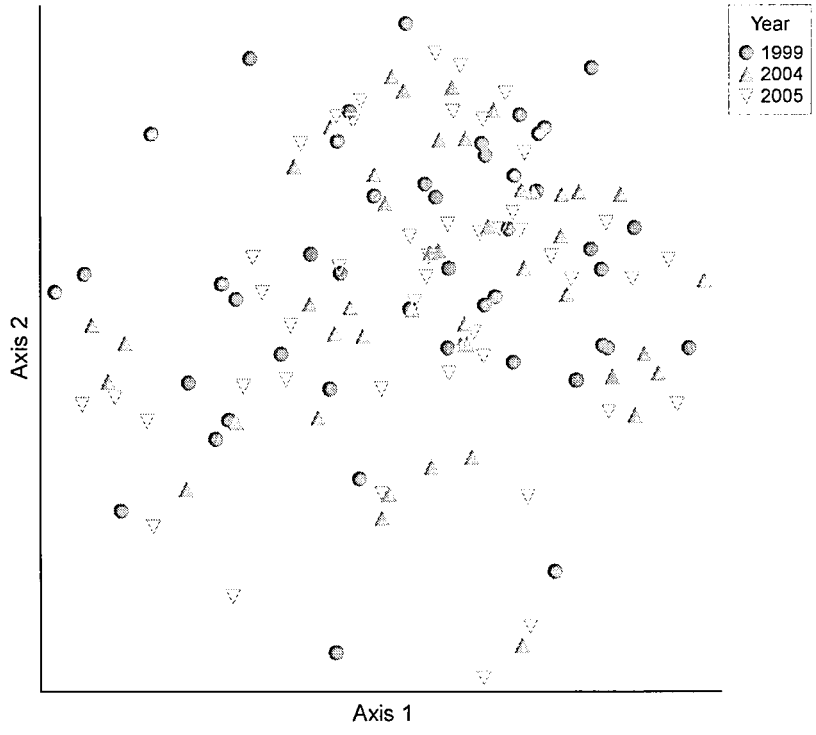

Figure 15. Forest understory plot ordination comparing 1999, 2004, and 2005 composition; axis 1 versus axis 2 for 3 dimensional ordination (Stress 17.8).

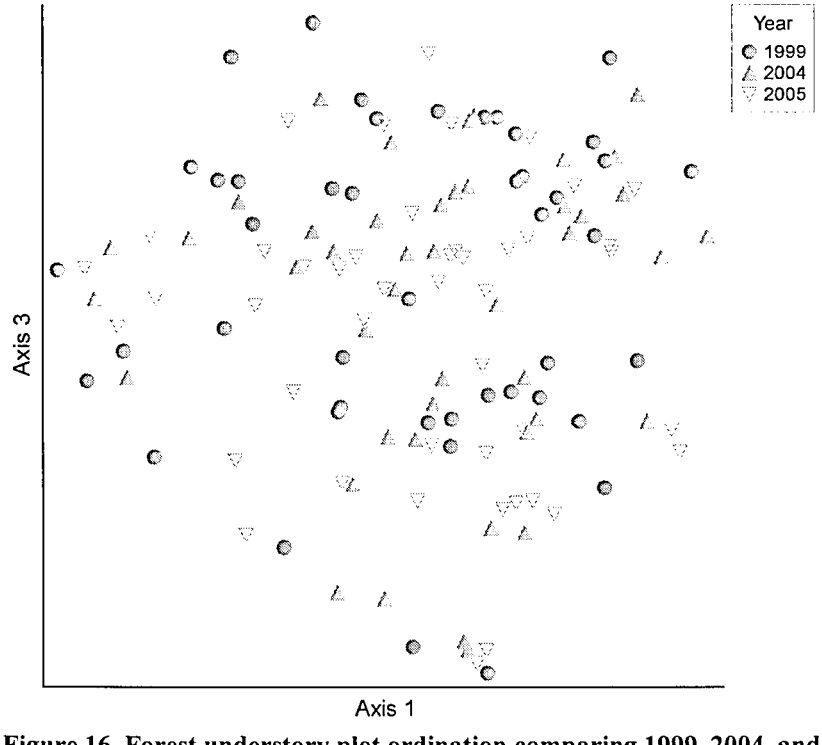

Figure 16. Forest understory plot ordination comparing 1999, 2004, and 2005 composition; axis 1 versus axis 3 for 3 dimensional ordination (Stress 17.8).

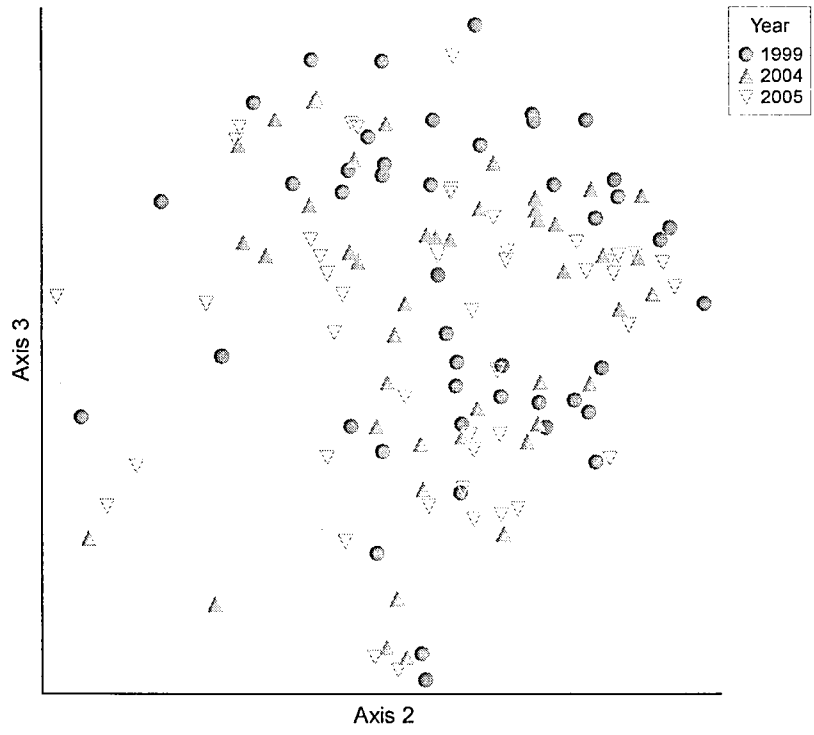

Figure 17. Forest understory plot ordination comparing 1999, 2004, and 2005 composition; axis 2 versus axis 3 for 3 dimensional ordination (Stress 17.8).

Riparian meadows

The two riparian meadow transects were established to assess possible impacts of biocontrol agent on spotted knapweed. Although these insects are not particularly well adapted to shady riparian habitats, we had no other feasible knapweed treatments methods for this herbicide restricted riparian area. Knapweed canopy cover and rosette density were significantly lower in 2004 than in 1997 (Tables 13 and 14). However the density of mature knapweed plants did not change significantly in either meadow. *Agapeta zoegana* (knapweed root moth) and *Cyphocleonus achates* (knapweed root weevil) attach larger mature knapweed plants rather than the small rosettes. Grass cover declined significantly in the small meadow (Table 13). Shrub cover increased in both meadows but the increase was not statistically significant; the shrub cover was highly variable among microplots. The decreases in herbaceous layer canopy cover and knapweed rosette density were likely due to a combination of increased shading from woody overstory and the protracted droughty conditions. However we did not actually measure shading from riparian overstory trees and shrubs.

Table 13. Small riparian meadow site vegetation in 1997 and then in 2004 (n=11 microplots).

Variable	1997 Mean	2004 Mean	2004-1997 Difference	p.†
% canopy cover				
Spotted knapweed	39.1	28.5	-10.6	.008
Sulfur cinquefoil	0.6	0.9	0.2	.588
Other Weeds	0.2	0.0	-0.2	.016
Grasses	16.7	6.5	-10.2	.003
Other Forbs	1.1	3.8	2.7	.116
Shrubs	0.3	13.2	12.9	.150
Total Canopy Cover	58.0	52.8	-5.2	.655
spotted knapweed				
Mature stem density	5.8	8.8	3.0	.122
Rosette density	52.5	11.5	-40.9	.017

†significance of two tailed paired t test

Table 14. Large riparian meadow site vegetation in 1997 and then in 2004 (n=14 microplots).

Variable	1997 Mean	2004 Mean	2004-1997 Difference	p.†
% canopy cover				
Spotted knapweed	37.1	30.2	-6.9	.027
Sulfur cinquefoil	0.3	0.7	0.4	.317
Other Weeds	0.0	0.0	0.0	.336
Grasses	2.9	5.7	2.8	.340
Other Forbs	0.2	3.1	2.9	.085
Shrubs	4.1	11.2	6.8	.380
Total Canopy Cover	44.6	50.1	5.5	.463
spotted knapweed				
Mature stem density	8.5	8.4	-0.1	.804
Rosette density	24.8	11.3	-13.5	.001

†significance of two tailed paired t test

Grassland fuel consumption

The upper two-thirds of the grassland were burned on November 7 and 9, 2001. The burned area encompassed thirty-five fuel transects. Total fuel load averaged 1,947 lbs/ac (Table 15). Consumption by the fire was 1,110 lbs/ac (57%). Approximately three-quarters of the standing dead fuels were burned including the perennial grasses. However only one-third of the litter was consumed.

Table 15. Table 15. Fuel load and consumption for the fall 2001 upper grassland burn.

	Lbs/ac			%
Fuel	Pre-burn	Post-burn	Consumed	Consumed
Cheatgrass	38	4	34	88%
Other Grasses	749	249	500	67%
Knapweed	46	12	35	75%
Other Forbs	441	115	326	74%
Litter	672	457	215	32%
Total	1,947	837	1,110	57%

Six of the thirty-five fuel transects were in areas that did not carry the low severity fire. Total fuel load for the no-burn transects averaged 1,445 lbs/ac and 2,050 lbs/ac for the burned area transects but this difference was not significant (p=0.269) (Table 16). However the no-burn area did include the two transects with the lowest (<900 lbs/ac) total fuel loads.

Table 16. Burn transects vs. no-burn transects F-test two-sample for variances.

Total Fuel	No Burn	Burned
Mean lbs/acre	1,445	2,050
Variance	395,702	708,898
Observations	6	29
Df	5	28
F	0.558	
P(F<=f) one-tail	0.269	
F Critical one-tail	0.222	

The lower grasslands were not burned. Depending on the year, the fuel loads and/or the conditions precluded implementing the burn prescriptions for the lower third of the grasslands.

Conclusions

Spotted knapweed was nearly totally suppressed by one time spraying of 1 pt/ac of Tordon on the test plots in the fall of 1996 and the 156 acres of extensive grasslands in the fall of 1998. Some reestablishment of knapweed, from seed in the soil, was evident in the second to fourth years after spraying. However, knapweed abundance at eight years post-spray on the test plots and at six years post-spray in the extensive grasslands remained a fraction of the pre-spray infestation. Knapweed averaged 202 lbs/ac on the test plots in 2004 at six years post-spray versus 414 lbs/ac on the no-spray check plots. Absolute canopy cover of spotted knapweed in the extensive grasslands had been reduced from 25% to 3% in 1999 and remained below 4% through 2004. The second herbicide treatment, helicopter application of 2/3 pt/ac Transline, reduced the knapweed to zero or trace amounts for both of the post secondary spray growing seasons.

In 1996 before the start of herbicide treatments there was more knapweed biomass than bunchgrasses in the RNA. Bunchgrass abundance increased dramatically after the initial spraying had reduced competition from knapweed. Bunchgrass growth remained vigorous through eight and six years post-spray in both monitoring networks. Grass standing crop eight years post-spray on the test plots averaged 606 lbs/ac compared to 202 lbs/ac on the no-spray controls. The second herbicide treatment induced another dramatic increase in bunchgrass abundance. The restored bunchgrasses continue to be vigorous. This vigorous grass competition slows reestablishment of spotted knapweed. Bunchgrass production on the test plots at the conclusion of measurements was 387 lbs/ac compared to 3 lbs/ac of knapweed. A return to the extremely suppressed pre-spray state is likely to take at least one to several decades if the early spring elk grazing pressure does not become even more excessive

Overall forb abundance declined slightly in the first growing season after both of the fall herbicide treatments but recovered in subsequent growing seasons. From 2002 on the relative abundance of non-target forbs equaled or exceeded what was present before the initiation of herbicide treatments.

Species diversity measurements corresponded more with a prolonged precipitation deficit than herbicide treatments. Average species richness and Shannon-Weaver diversity have not returned to the highs measured in 1995. At least part of the diversity decline for the first three years after the initial herbicide treatment is attributable to Tordon spraying impacting forbs, but in the later half of the monitoring period the drought effect was the factor influencing diversity. The total number of plant species in each yearly sample ranged from 73 to 78 over the period from pre-spray through six years post initial spray, having been depressed in the second year post-spray then returning to pre-spray totals in the third year post-spray (1999). Cumulative drought conditions beginning in 1999 became the major factor suppressing forb species presence. Total species richness declined sharply after 2002 (six years post spray) when there was no herbicide residue left in the system. The second herbicide treatment had no measurable impact on diversity. There was even a small increase in diversity in the second growing season after spraying Transline. Transline is the most selective of the

knapweed herbicides. Overall the spraying impacts on forb diversity were small and transitory.

Cheatgrass abundance has changed little in the years post-spray at Sawmill where the herbicide rate was 1 pint/acre or less and residual native grasses were available to replace the spotted knapweed. Cheatgrass did increase subsequent to spraying at higher Tordon application rates in eradication target species infested areas where the native grasses had previously been nearly eliminated by noxious weed competition.

The goatweed infestation has been contained within its 1995 boundaries by a combination of spraying and *Chrysolina* beetles. The single leafy spurge colony may have been eradicated. The size of individual dalmatian toadflax colonies and the number of stems within these individual colonies have been reduced by repeat herbicide applications, but approximately one new colony is being found every year or two such that the total area with dalmatian toadflax infestation has remained approximately the same. Plateau treatments of dalmatian toadflax were less effective than the multi-quart Tordon treatments.

At the start of this study plant community composition of the vegetation at Sawmill was distinctively different from the potential natural communities as defined by the Mueggler and Stewart habitat type definition plots. Both herbicide treatments were followed by marked increases in similarity to the potential natural communities for all three habitat types that were monitored. However, these herbicide induced improvements towards the "natural" vegetative state of these habitat types were not persistent. Retrogression of the floristic trajectories was evident several years after the herbicide induced improvements. Heavy elk grazing and fire were degrading factors as well as knapweed reestablishment. Yearly variability in climatic conditions undoubtedly contributed to the shifts in similarity, and cumulative drought conditions may have also inhibited fuller restoration of the potential natural communities. However, at the conclusion of the monitoring effort the sprayed Idaho fescue/bluebunch wheatgrass plots were more similar to the potential natural community than the no-spray weedy check plots (Figure 18).

Silvacultural treatments to restore a more open forest canopy structure had little impact on the forest understory vegetation. Thinning, pile and broadcast burning create surface disturbances that, along with more sunlight penetration to the forest floor, might facilitate knapweed increases in the forest herbaceous layer. However the low abundance of knapweed in the forested ravines did not change during the six year period of monitoring the forested habitat types at Sawmill even with these disturbances. Spraying the heavily infested surrounding grasslands before beginning forest restoration treatments suppressed knapweed propagule pressure as did spot spraying of preexisting knapweed colonies within the forested ravines. Helicopter application of Transline to the forested ravines had no detectable effect on the herbaceous community composition or diversity, but may have prevented potential increases in knapweed abundance because of the broadcast burn.

Several biocontrol insect species attacking spotted knapweed or goatweed are well established in the RNA and probably contributing to longer term suppression of these weeds.

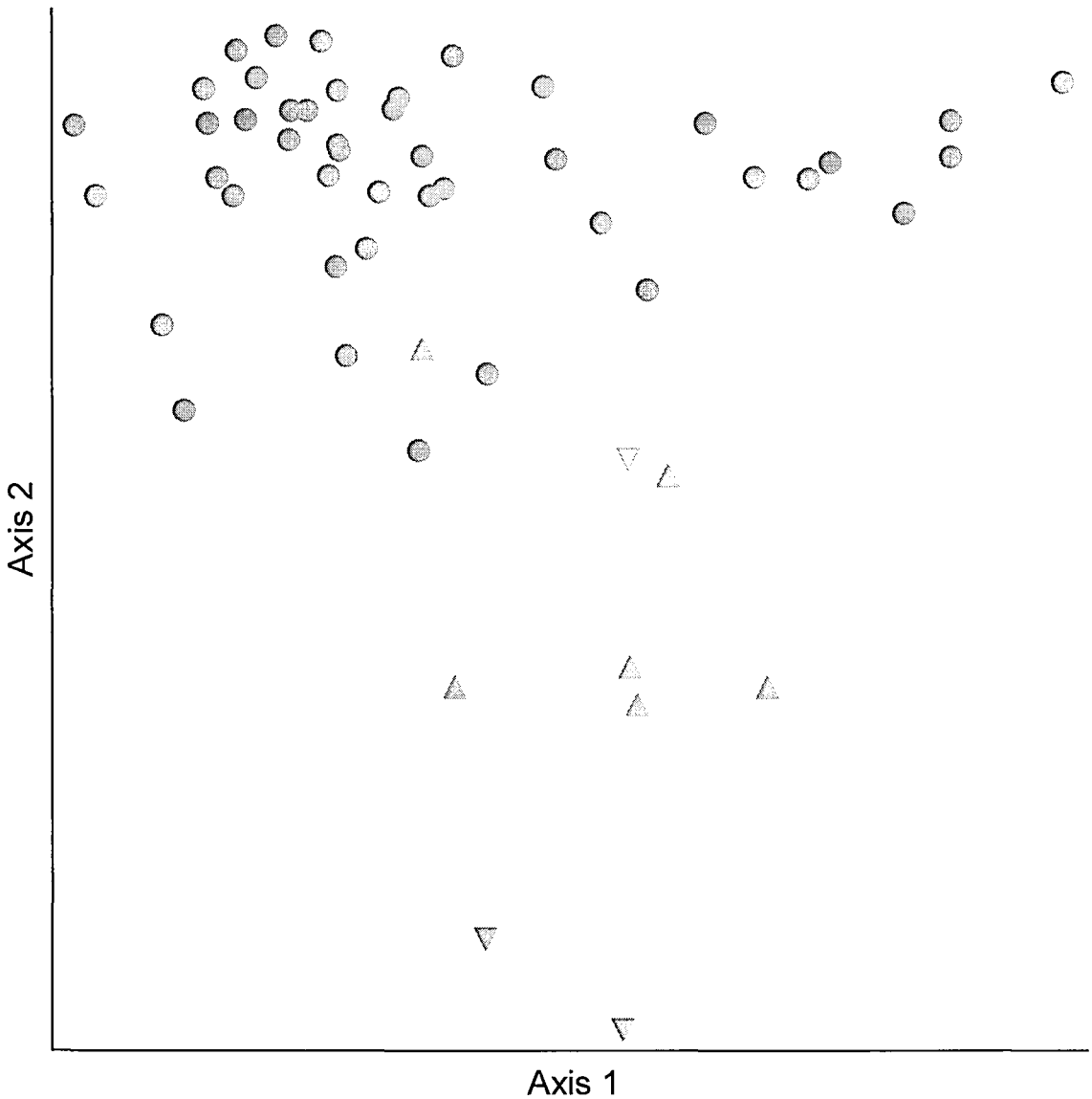

Figure 18. Sawmill Idaho fescue/bluebunch wheatgrass plots in 2006 compared to the Mueggler and Stewart habitat type definition plots ; Sawmill sprayed weedy plots , no-spray weedy check plots , not weedy check plot (2 Dimensional Stress 13.7).

Appendices

Methodological References

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A[redacted]x Table 17. Plot treatment and sampling summary for 0.1 acre [redacted]ental test plots, efficacy & fuel transects

plot	Enclosed	pair	Habitat type	plot type†	Purpose	road	herbicide	burn	1995	1996	1997	1998	1999	2000	2001	2002†	2004	2005	2006	plot
904	y	3	ARTR/FESC	full community	full community	below	tordon Sept 96-1pint, transline Oct 04 2/3 pint		s	n	n	s	s	n	n	s	s	s	s	904
905	n	3	ARTR/FESC	full community	full community	below	tordon Sept 96-1pint, transline Oct 04 2/3 pint		s	n	n	s	s	n	n	s	s	s	s	905
911	y	2	FEID/AGSP	full community	full community	above	tordon Sept 96-1pint, transline Oct 04 2/3 pint	Nov-01	s	n	n	s	s	n	s	s	s	s	s	911
922	n	2	FEID/AGSP	full community	full community	above	tordon Sept 96-1pint, transline Oct 04 2/3 pint	Nov-01	n	s	n	s	s	n	s	s	s	s	s	922
902	y	4	FEID/AGSP	full community	full community	below	tordon Sept 96-1pint, transline Oct 04 2/3 pint		s	n	n	s	s	n	s	s	s	s	s	902
916	n	4	FEID/AGSP	full community	full community	below	tordon Sept 96-1pint, transline Oct 04 2/3 pint		s	n	n	s	s	n	s	s	s	s	s	916
903	n		FEID/AGSP	full community	full community	above	tordon Sept 96-1pint, transline Oct 04 2/3 pint	Nov-01	s	n	n	s	s	n	s	s	s	s	s	903
906	n		FEID/AGSP	full community	full community	above	tordon Sept 96-1pint, transline Oct 04 2/3 pint	Nov-01	s	n	n	s	s	n	s	s	s	s	s	906
910	y	1	FESC/FEID	full community	full community	above	tordon Sept 96-1pint, transline Oct 04 2/3 pint	Nov-01	s	n	n	s	s	n	s	s	s	s	s	910
909	n	1	FESC/FEID	full community	full community	above	tordon Sept 96-1pint, transline Oct 04 2/3 pint	Nov-01	s	n	n	s	s	n	s	s	s	s	s	909
901	n		FEID/AGSP	short nested	Goatweed	below	tordon June 95-3pts, transline Oct 04 2/3 pint		s	s	s	s	s	n	n	s	s	s	s	901
908	n		FEID/AGSP	short nested	Goatweed	below	tordon June 95-3pts, transline Oct 04 2/3 pint		s	s	s	s	s	n	n	s	s	s	s	908
917	n		PIPO	short nested	Goatweed	below	tordon June 95-3pts	out	s	s	s	s	s	n	n	s	s	n	n	917
915	n		ARTR/FESC	short nested	not weedy check	above	nonspray, transline Oct 04 2/3 pint	Nov-01	s	n	n	n	s	n	n	s	n	s	s	915
914	n		FEID/AGSP	short nested	not weedy check	above	nonspray, transline Oct 04 2/3 pint	poor	s	n	n	n	s	n	n	s	s	s	s	914
913	n		FESC/FEID	short nested	not weedy check	above	nonspray, transline Oct 04 2/3 pint	poor	s	n	n	n	s	n	n	s	s	s	s	913
912	n		FEID/AGSP	short nested	short nested	above	tordon Sept 96-1pint, transline Oct 04 2/3 pint	Nov-01	s	n	n	s	s	n	n	s	s	n	n	912
919	n		FEID/AGSP	short nested	short nested	below	tordon Sept 96-1pint, transline Oct 04 2/3 pint		s	n	n	s	s	n	n	s	s	s	n	919
907	n		PIPO	short nested	short nested	below	tordon Sept 96-1pint, transline Oct 04 2/3 pint	out	s	n	n	s	s	n	n	n	s	s	s	907
921	n		PSME	short nested	short nested	above	tordon Sept 96-1pint, transline Oct 04 2/3 pint	out	s	n	n	s	s	n	n	n	s	n	n	921
918	n		FEID/AGSP	short nested	weedy check	below	nonspray		s	n	n	n	s	n	s	s	s	s	s	918
920	n		FEID/AGSP	short nested	weedy check	below	nonspray, transline Oct 04 2/3 pint		s	n	n	s	s	n	s	s	s	s	s	920
923	n	L,R	ARTR/FESC	Transect pair	elk pellets, spray efficacy	below	Tordon Oct 98-1pint, transline Oct 04 2/3 pint				sp*	sp, se*	sp, se	n	se	se	se	se	n	923
924	n	L,R	FEID/AGSP	Transect pair	elk pellets, spray efficacy	below	Tordon Oct 98-1pint, transline Oct 04 2/3 pint				sp	sp, se	sp, se	n	se	se	se	se	n	924
925	n	L,R	FEID/AGSP	Transect pair	elk pellets, spray efficacy	above	Tordon Oct 98-1pint, transline Oct 04 2/3 pint	Nov-01			sp	sp, se	sp, se	n	se	se	se	n	n	925

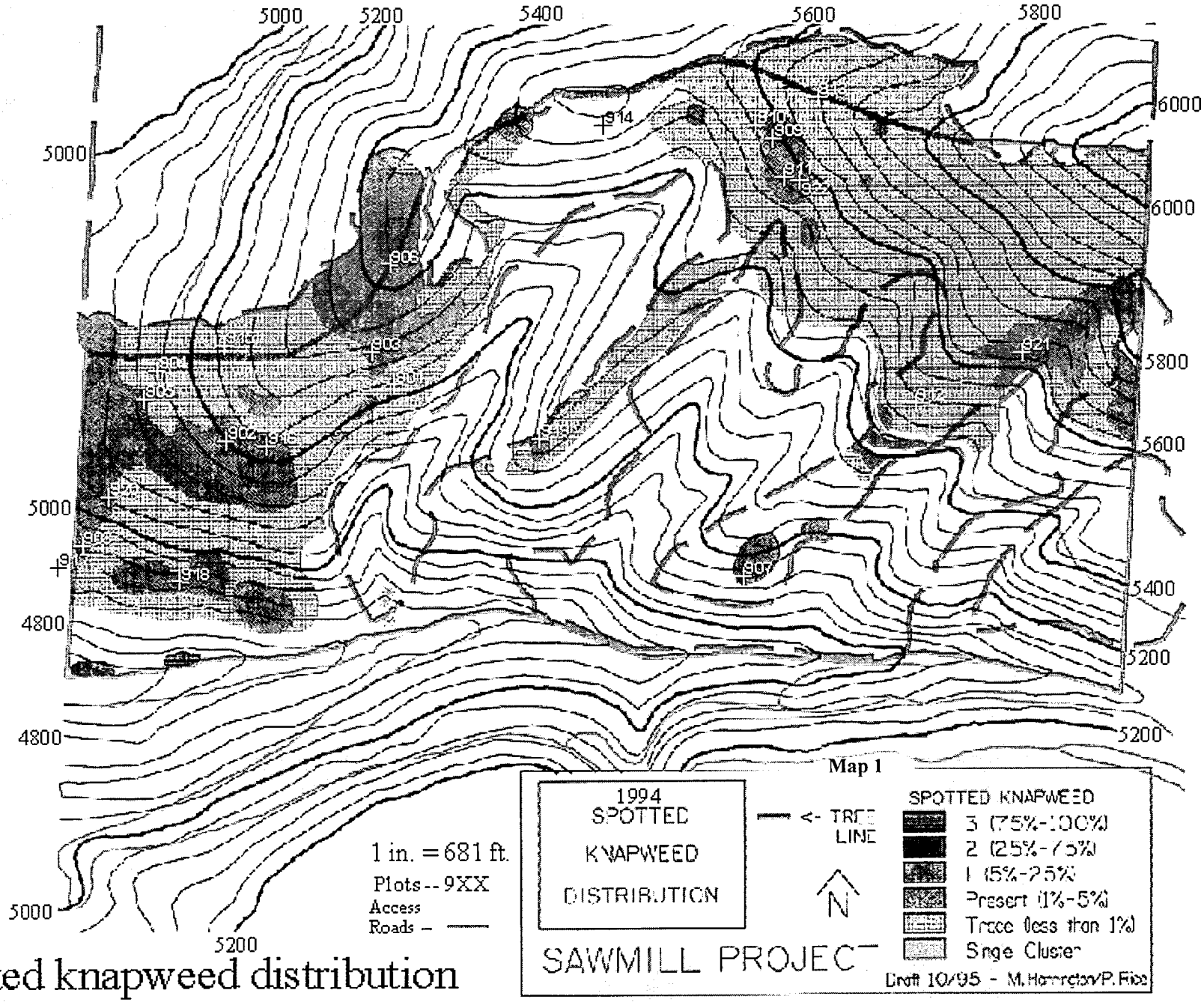
plot	enclosed	pair	Habitat type	plot type†	Purpose	road	herbicide	burn	1995	1996	1997	1998	1999	2000	2001	2002†	2004	2005	2006	plot
926	n	L,R	FEID/AGSP	Transect pair	elk pellets, spray efficacy	above	Tordon Oct 98-1pint, transline Oct 04 2/3 pint	Nov-01			sp	sp, se	sp, se	n	se	se	se	se	n	926
927	n	L,R	FESC/FEID	Transect pair	elk pellets, spray efficacy	above	Tordon Oct 98-1pint, transline Oct 04 2/3 pint	Nov-01			sp	sp, se	sp, se	n	se	se	se	se	n	927
928	n	L,R	FEID/AGSP	Transect pair	elk pellets, spray efficacy	above	Tordon Oct 98-1pint, transline Oct 04 2/3 pint	poor			sp	sp, se	sp, se	n	se	se	se	se	n	928
929	n	L,R	PSME	Transect pair	elk pellets, spray efficacy	above	Tordon Oct 98-1pint, transline Oct 04 2/3 pint	out			sp	sp, se	sp, se	n	se	n	se	se	n	929
930	n			fuel transect	fuels, burn response	above	Tordon Oct 98-1pint, transline Oct 04 2/3 pint	Nov-01							se	se	se	se	n	930
931	n			fuel transect	fuels, burn response	above	Tordon Oct 98-1pint, transline Oct 04 2/3 pint	Nov-01							se	se	se	se	n	931
932	n			fuel transect	fuels, burn response	above	Tordon Oct 98-1pint, transline Oct 04 2/3 pint	Nov-01							se	se	se	se	n	932
933	n			fuel transect	fuels, burn response	above	Tordon Oct 98-1pint, transline Oct 04 2/3 pint	Nov-01							se	se	se	se	n	933
934	n			fuel transect	fuels, burn response	above	Tordon Oct 98-1pint, transline Oct 04 2/3 pint	Nov-01							se	se	se	se	n	934
935	n			fuel transect	fuels, burn response	above	Tordon Oct 98-1pint, transline Oct 04 2/3 pint	Nov-01							se	se	se	se	n	935
936	n			fuel transect	fuels, burn response	above	Tordon Oct 98-1pint, transline Oct 04 2/3 pint	Nov-01							se	se	se	se	n	936
937	n			fuel transect	fuels, burn response	above	Tordon Oct 98-1pint, transline Oct 04 2/3 pint	Nov-01							se	se	se	se	n	937
938	n			fuel transect	fuels, burn response	above	Tordon Oct 98-1pint, transline Oct 04 2/3 pint	Nov-01							se	se	se	se	n	938
939	n			fuel transect	fuels, burn response	above	Tordon Oct 98-1pint, transline Oct 04 2/3 pint	Nov-01							se	se	se	se	n	939
940	n			fuel transect	fuels, burn response	above	Tordon Oct 98-1pint, transline Oct 04 2/3 pint	Nov-01							se	se	se	se	n	940
941	n			fuel transect	fuels, burn response	above	Tordon Oct 98-1pint, transline Oct 04 2/3 pint	Nov-01							se	se	se	se	n	941
942	n			fuel transect	fuels, burn response	above	Tordon Oct 98-1pint, transline Oct 04 2/3 pint	Nov-01							se	se	se	se	n	942
943	n			fuel transect	fuels, burn response	above	Tordon Oct 98-1pint, transline Oct 04 2/3 pint	Nov-01							se	se	se	se	n	943
944	n			fuel transect	fuels, burn response	above	Tordon Oct 98-1pint, transline Oct 04 2/3 pint	Nov-01							se	se	se	se	n	944
945	n			fuel transect	fuels, burn response	above	no weeds, transline Oct 04 2/3 pint	Nov-01							se	se	se	se	n	945
946	n			fuel transect	fuels, burn response	above	no weeds, transline Oct 04 2/3 pint	no							se	se	se	se	n	946
947	n			fuel transect	fuels, burn response	above	no weeds, transline Oct 04 2/3 pint	no							se	se	se	se	n	947
948	n			fuel transect	fuels, burn response	above	no weeds, transline Oct 04 2/3 pint	no							se	se	se	se	n	948
949	n			fuel transect	fuels, burn response	above	no weeds, transline Oct 04 2/3 pint	Nov-01							se	se	se	se	n	949

plot	enclosed	pair	Habitat type	plot type†	Purpose	road	herbicide	burn	1995	1996	1997	1998	1999	2000	2001	2002†	2004	2005	2006	plot
950	n			fuel transect	fuels, burn response	above	no weeds, transline Oct 04 2/3 pint	Nov-01							se	se	se	se	n	950
951	n			fuel transect	fuels, burn response	below	low, steep, transline Oct 04 2/3 pint								se	se	se	se	n	951
952	n			fuel transect	fuels, burn response	below	low, steep, transline Oct 04 2/3 pint								se	se	se	se	n	952
953	n			fuel transect	fuels, burn response	below	?Tordon Oct 98-1pint, transline Oct 04 2/3 pint									se	se	se	n	953
954	n			fuel transect	fuels, burn response	below	?Tordon Oct 98-1pint, transline Oct 04 2/3 pint									se	se	se	n	954
955	n			fuel transect	fuels, burn response	below	?Tordon Oct 98-1pint, transline Oct 04 2/3 pint									se	se	se	n	955
956	n			fuel transect	fuels, burn response	below	?Tordon Oct 98-1pint, transline Oct 04 2/3 pint									se	se	se	n	956
957	n			fuel transect	fuels, burn response	below	?Tordon Oct 98-1pint, transline Oct 04 2/3 pint									se	se	se	n	957
958	n			fuel transect	fuels, burn response	below	?Tordon Oct 98-1pint, transline Oct 04 2/3 pint									se	se	se	n	958
959	n			fuel transect	fuels, burn response	below	?Tordon Oct 98-1pint, transline Oct 04 2/3 pint									se	se	se	n	959
960	n			fuel transect	fuels, burn response	below	?Tordon Oct 98-1pint, transline Oct 04 2/3 pint									se	se	se	n	960
961	n			fuel transect	fuels, burn response	below	?Tordon Oct 98-1pint, transline Oct 04 2/3 pint									se	se	se	n	961
962	n			fuel transect	fuels, burn response	below	?Tordon Oct 98-1pint, transline Oct 04 2/3 pint									se	se	se	n	962
963	n			fuel transect	fuels, burn response	below	?Tordon Oct 98-1pint, transline Oct 04 2/3 pint									se	se	se	n	963
964	n			fuel transect	fuels, burn response	below	?Tordon Oct 98-1pint, transline Oct 04 2/3 pint									se	se	se	n	964
965	n			fuel transect	fuels, burn response	below	?Tordon Oct 98-1pint, transline Oct 04 2/3 pint									se	se	se	n	965
966	n			fuel transect	fuels, burn response	below	?Tordon Oct 98-1pint, transline Oct 04 2/3 pint									se	se	se	n	966
967	n			fuel transect	fuels, burn response	below	?Tordon Oct 98-1pint, transline Oct 04 2/3 pint									se	se	se	n	967
968	n			fuel transect	fuels, burn response	below	?Tordon Oct 98-1pint, transline Oct 04 2/3 pint									se	se	se	n	968
969	n			fuel transect	fuels, burn response	below	?Tordon Oct 98-1pint, transline Oct 04 2/3 pint									se	se	se	n	969

** s = sampled in year indicated, sp = sampled for elk pellets, se = sampled for efficacy of extensive (156 acres) grassland spraying

† starting in 2002 full-community sampling was carried out on all tenth-acre plots including those originally designated as short nested plots

Appendix Figure 19. Map of permanent plot locations (and 1994 knapweed distribution).



Spotted knapweed distribution

Appendix Table 18. Coordinates (degrees and decimal minutes) for plots and transect ends.

Plot	Side	Lat N degrees	Lat minutes	Long W degrees	Long minutes	Lat2 N degrees	Lat2 minutes
904		46	27.09	113	54.30		
905		46	27.05	113	54.31		
911		46	27.28	113	53.06		
922		46	27.27	113	53.54		
902		46	27.02	113	54.21		
916		46	24.02	113	54.20		
903		46	27.07	113	54.01		
906		46	27.19	113	54.01		
910		46	27.33	113	53.60		
909		46	27.32	113	53.57		
901		46	27.05	113	54.04		
908		46	26.94	113	54.36		
917		46	27.09	113	54.00		
915		46	27.12	113	54.18		
914		46	27.30	113	53.76		
913		~ 300 ft NE of	Plots 910/909				
912		46	27.07	113	53.41		
919		46	27.01	113	53.86		
907		46	26.95	113	53.60		
921		46	27.11	113	53.27		
918		46	26.91	113	54.24		
920		46	26.99	113	54.33		
923	L	46	17.09	113	54.31	46	27.09
923	R	46	27.08	113	54.31	46	27.07
924	L	46	27.04	113	54.20	46	27.03
924	R	46	27.04	113	54.19	46	27.03
925	L	46	27.09	113	54.12	46	27.11
924	R	46	27.04	113	54.19	46	27.03
926	L	46	27.22	113	53.99	46	27.23
926	R	46	27.22	113	53.98	46	27.23
927	L	46	27.35	113	53.58	46	27.34
927	R	46	27.34	113	53.58	46	27.34
928	L	46	27.31	113	53.50	46	27.30
928	R	46	27.30	113	53.51	46	27.31
929	L	46	27.12	113	53.31	46	27.11
929	R	46	27.12	113	53.29	46	27.13
930		46	27.24	113	53.59	46	27.24
931		46	27.14	113	53.36	46	27.13
932		46	27.20	113	53.44	46	27.20
933		46	27.21	113	53.48	46	27.21
934		46	27.25	113	53.51	46	27.23
935		46	27.27	113	53.48	46	27.27
936		46	27.24	113	53.44	46	27.24
937		46	27.22	113	53.39	46	27.22
938		46	27.20	113	53.34	46	27.19

[redacted]ot	Side	Lat N degrees	Lat minutes	Long W degrees	Long minutes	Lat2 N degrees	Lat2 minutes
[redacted]939		46	27.20	113	53.30	46	27.19
940		46	27.24	113	53.35	46	27.23
941		46	27.26	113	53.40	46	27.25
942		46	27.27	113	53.44	46	27.27
943		46	27.30	113	53.46	46	27.29
944		46	27.32	113	53.64	46	27.31
945		46	27.28	113	53.71	46	27.27
946		46	27.27	113	53.77	46	27.26
947		46	27.25	113	53.83	46	27.25
948		46	27.29	113	53.77	46	27.28
949		46	27.28	113	53.81	46	27.28
950		46	27.28	113	53.86	46	27.28
951		46	26.92	113	54.12	46	26.91
952		46	26.91	113	54.17	46	26.91
953		46	27.05	113	54.32	46	27.04
954		46	27.03	113	54.31	46	27.02
955		46	27.01	113	54.29	46	27.01
956		46	27.00	113	54.27	46	27.00
957		46	27.00	113	54.27	46	26.99
958		46	26.99	113	54.24	46	26.99
959		46	26.98	113	54.22	46	26.98
960		46	26.98	113	54.19	46	26.98
961		46	26.09	113	54.02	46	27.07
962		46	26.92	113	54.40	46	27.08
963		46	27.08	113	54.01	46	27.09
964		46	27.02	113	53.80	46	27.01
965		46	27.03	113	53.77	46	27.03
966		46	27.06	113	53.75	46	27.05
967		46	27.03	113	53.82	46	27.03
968		46	27.04	113	53.79	46	27.04
969		46	27.06	113	53.76	46	27.05

Progress Report for Sampling Through 2006
December 29, 2006

Agreement # 02-JV-11222048-141

The Impact of Prescribed Fire Following Either Herbicide or Thinning Treatments on Bunchgrass and Forested Ecosystems in the Sawmill Creek Research Natural Area

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&
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Introduction

The Forest Service established the 270 acre Sawmill Research Natural Area in the Sapphire Range of the Bitterroot National Forest because it was one of our best remaining examples of native bunchgrass and open canopy forest habitat types. The RNA is also an important elk winter range. However, invasion of the RNA by exotic plants is degrading the grasslands, and Douglas-fir encroachment of the forested ravines, because of fire suppression, is altering the species composition and structure of the forest types. We mapped the distribution of noxious weeds in 1994 and developed a restoration plan in 1995. The overall strategy is to first suppress the noxious weeds in the grasslands, reduce stand density in the forested ravines by thinning, and then return fire through prescribed burning to the grasslands and the forested areas. This is an integrated weed control and restoration demonstration project at the management unit scale, in addition to a focused restoration effort for the altered ecosystems of this RNA. We installed an extensive network of vegetation monitoring plots to provide scientific documentation of progress in returning the potential natural vegetation. This will allow for an assessment of the impact of future treatments and disturbance, natural or otherwise. Our intent is that site tours and technical reports be used for public and professional staff education, developing environmental impact statements, and restoration planning.

We began plan implementation in 1995 by setting up herbicide test plots and introducing knapweed biocontrol insects. The 1996 trial spray treatments were successful in driving the plant community composition to a state more similar to the potential natural vegetation as defined by the Mueggler and Stewart habitat types found on the RNA. In 1998 nearly the entire grassland (~160 acres) was sprayed. Bunchgrass cover was restored to the site and native forb diversity was maintained. The biomass that had been represented as coarse-stemmed knapweed was converted to fine grass. In 1999 the Douglas-fir understory was slashed and piled, and selected larger Douglas-firs were girdled. The piles were burned in the fall of 1999. The Stevensville Ranger District broadcast burned the upper 2/3 of the RNA in November 2001. The forested ravines below the lower road were burned on April 5, 2004 by the Stevensville Ranger District in cooperation with Mick Harrington from the Missoula Fire Sciences Laboratory. We have not been able to burn the grasslands below the lower road because fuels have been

insufficient to carry the fire under cool season conditions. The entire grasslands, including the initial herbicide test plots, and forested ravines were helicopter sprayed with Transline at 2/3 pint/acre on October 1, 2004.

Changes in species composition, biomass production, and fuel loads during the course of this restoration demonstration project are being measured by an extensive network of sampling plots and transect. We have been making measurements on a near-yearly basis depending on availability of funding.

Site Description

Sawmill Creek Research Natural Area (RNA) is located in the northeastern portion (T8N,R18W Sect 18) of the Bitterroot National Forest on the Stevensville Ranger District in western Montana. It is primarily a south facing slope system. Several forested ravines dissect a montane grassland. The area totals 270 acres. The RNA supports a mosaic of dry conifer forest and mountain grassland habitat types. The most common tree species in 1999 was Douglas-fir (*Pseudotsuga menziesii*) making up 70% of the stand density. Twenty-two percent of the stand was ponderosa pine (*Pinus ponderosa*), the historic dominant. The remaining 8% was Rocky Mountain juniper (*Juniperus scopulorum),* which has increased along with Douglas-fir in the last 75 years during the fire suppression era. The trees form park-like stands on dry sites and closed canopy forests on the more mesic ravine sites but the Douglas-fir proliferation has caused increased competition and ladder fuels throughout the RNA. The mountain grasslands that should be dominated by bluebunch wheatgrass (*Agropyron spicatum*), Idaho fescue (*Festuca idahoensis*) and rough fescue (*Festuca scabrella*) occupy about 40% of the RNA.

The area has been subjected to grazing by both livestock and elk herds. There is no written record for the area prior to 1944 but it is said that it was used heavily for years by private landowners. Records of the area were kept from 1944 on by the BNF, and provide a history of only moderate to light livestock use after the 1950's. In May of 1992 the area was designated as an RNA to provide an example of five natural communities:

rough fescue/Idaho fescue h.t.
Idaho fescue/bluebunch wheatgrass h.t.
ponderosa pine/Idaho fescue h.t.
Douglas-fir/Idaho fescue h.t.
Douglas-fir/bluebunch wheatgrass h.t.

The major objective of establishing Sawmill Creek RNA was to maintain and preserve these habitat types in as near an undisturbed (by modern humans) condition as possible.

Although the Sawmill RNA was believed to contain the best remaining example of rough fescue/Idaho fescue habitat type on the Bitterroot National Forest, and superior

examples of the other four habitat types, like most of the western US, it has not completely escaped the invasion of exotic weed species. In 1994 we mapped the distribution of ten of the most problematic exotic species that had invaded the unit.

Target	Acres	Objective
spotted knapweed (*Centaurea maculosa*)	153 acres	suppress
leafy spurge (*Euphorbia esula*)	<0.01 acres	eradicate
sulfur cinquefoil (*Potentilla recta*)	0.28 acres	suppress
dalmatian toadflax (*Linaria dalmatica*)	<0.01 acres	eradicate
St. Johnswort* (*Hypericum perforatum*)	4.2 acres*	contain
common tansy (*Tanacetum vulgare*)	<0.01 acres	contain
houndstongue (*Cynoglossum officinale*)	<0.01 acres	contain
musk thistle (*Carduus nutans*)	0.24 acres	suppress
Canada thistle (*Cirsium arvense*)	<0.01 acres	suppress
common mullein (*Verbascum thapsus*)	14.2 acres	tolerate

* also called goatweed, 2.7 acres within the RNA and 1.5 acres along the west boundary

Suppression, containment, or eradication where feasible, of most of these exotics was desirable to obtain the principal management goal of maintenance of the natural climax communities for this site.

Douglas-fir establishment in the understory had been extensive throughout the forested areas of the RNA. Dwarf-mistletoe and several root diseases were prevalent in all size classes of Douglas-fir. Removal of understory and midstory Douglas-fir was necessary to reduce the probability of stand replacing fires and decrease the competitive pressure on ponderosa pine. Conifers had also encroaching the grassland habitat types and junipers are now a significant component at the lower elevations.

Methods

Plant community composition was first determined in 1995 prior to any herbicide treatment of test/demonstration plots or spraying of the extensive grassland habitats. Permanent monitoring plots were established in each of the major habitat types. Plots were 0.1 acre (66'x66'). Nineteen plots were placed in the grassland habitat types and three in open forest habitat types. The plots were located using a stratified random design. Each of the twenty-two permanent monitoring plots has five randomly placed transects with five microplots per transect. Plot corners and 5 random transects per plot were permanently marked with wooden stakes and iron rebar. Five 10x20 inch microplot locations per transect were permanently marked with brightly painted nails to allow precise relocation. Species composition was determined by Daubenmire canopy cover techniques. Fixed Daubenmire frame locations will allow repeated measures for subsequent years sampling.

We used the "Cover Microplot" and "Short Nested Microplot" sampling protocols developed as part of the standard Region 1 ECODATA methods (Hann & Jensen 1987) for grassland sampling.

Short Nested Microplot data was used to monitor target exotics and dominant natives that define the climax communities. These data are used to answer the question: are targeted exotics increasing or decreasing in the RNA? Goatweed (St. Johnswort) plots were read periodically through 2002. Three short nested plots were located in goatweed colonies that received their first herbicide treatments in 1995. Six short nested plots were located in areas with high weed densities including areas where cheatgrass (*Bromus tectorum* L.) density was high, and on sites where landscape features created special interest management areas (i.e. open ridgelines isolated by forest cover). Three short nested plots were also established in not-weedy areas to provide reference data from untreated portions of the RNA. The main 0.1 acre plot types, purpose, treatments, and sampling histories are summarized in the appendix table.

Full community measurement "Cover Microplots" were established in 1995 and 1996 to determine if the grassland plant communities are becoming more or less similar to the potential climax. A double stratified random design was used to locate ten of these plots in the weediest areas of 3 different grassland and shrub habitat types. These measurements were repeated in 1998, 1999, 2001, and 2002 to evaluate the response of the entire plant community to the fall 1996 herbicide treatments.

Elk exclosures were built around full community baseline monitoring plots at four locations. Each enclosure was paired with an adjacent, non-enclosed plot, and pair locations stratified by habitat type (appendix table). The elk enclosures are 75 ft × 75 ft and 6 ft tall (4 ft field wire along the bottom, with 3 strands of barbed wire above). Herbaceous standing crop in the 8 plots comprising the elk exclosure study was estimated by double sampling (Francis et al. 1979) for the following categories:

1) bluebunch wheatgrass (AGRSPI)
2) Idaho fescue (FESIDA)
3) rough fescue (FESSCA)
4) other grasses
5) spotted knapweed (CENMAC)
6) other forbs

Standing crop sampling is done near the period of peak biomass, starting before the fall 1996 herbicide applications. We made ocular estimates of green weight in 25 microplots (25 × 51 cm frames) per monitoring plot. Five randomly selected microplots per monitoring plot were also clipped. We calibrated estimated green weights to oven-dry weights by linear regression.

In 1998 fourteen new transects were established to monitor grassland response to the herbicide applications over the extensive grassland area planned for fall 1998. Transects were set in pairs forming two sides of 0.1 acre plots at seven locations.

Transect layouts are the same as used for the previously established monitoring plots: length 66 ft., 5 microplot locations at 12 ft. intervals, microplots 10 in. x 20 in. Canopy cover classes were estimated for 7 individual species and 4 other vegetation life form categories. Forty additional transects initially established for determining fuel loads throughout the entire grassland were also used to measure spraying efficacy and non-target plant response in 2004 and 2005

In addition to the ECODATA plots, "observation posts" were established in the small colonies of weeds that were targeted for eradication. These initially were eight dalmatian toadflax (*Linaria dalmatica* (L.) Mill.) colonies, and only one known leafy spurge (*Euphorbia esula* L.) colony. The initial centers of the colonies were permanently marked with steel fence posts. The usual ECODATA plots are not appropriate due to the small size of these colonies. At each observation post we record location and general site data, colony dimensions, approximate density of the target weed and ocular canopy cover estimates for the major native grasses and forbs within the colony. These points were inspected three times (spring, summer, fall) per year through 1999, then during the summer through 2002.

Forest understory sampling began in 1999 to characterize the entire forest understory response to herbicides and prescribed burning. The method is similar to the Daubenmire technique use for the main 0.1 acre plots, except a larger 143cm x 70cm (one square meter total) frame is used, with four frames per plot or location. There are 20 plots in the westerly-most forested ravine, and 25 to the east in the forested ravine in the center of the RNA.

Herbicide Treatments

In the fall of 1996 we made broadcast treatments for spotted knapweed control on 14 experimental monitoring plots. The timing corresponded to fall regrowth of knapweed rosettes. Each plot was treated with picloram (Tordon 22K) at the recommended rate for control of spotted knapweed (0.25 lb active ingredient/acre or 1 pint/acre Tordon 22K). The application dates were from September 26 through 30. An 80 by 80 foot area centered on each 1/10 acre plot was treated so there was a sprayed buffer between the surrounding weeds and the sampling plot.

During the period 9/26-10/31/98 the extensive grassland portions of the RNA were broadcast sprayed. The extensive grassland treatments had to be applied in a manner that avoided spraying a certain number of the permanent monitoring plots and biocontrol release plots. Herbicides were sprayed when weather conditions were favorable. ATV boom, truck-mounted handguns, and Solo backpacks were used. Most of the acreage was treated with the ATV-mounted boom. Tordon was applied at 1 pint / acre to 133.5 acres and Transline at 2/3 pint / acre to 18.9 acres. Total calculated coverage was 152.4 acres of the nominal 156 acres targeted for treatment.

Tree thinning was done in the ravines during the summer of 1999 and slash piles formed for burning in late fall. Prior to burning the slash piles in the west and central

ravines, the areas of forest openings with knapweed were sprayed with Tordon at 1 to 2 pts/acre and Transline at 2/3 pt/acre. The goal of spot spraying in the forest openings was to reduce weed spread into the bare soil of slash pile burn spots and other areas disturbed by the silvacultural preparations for broadcast burning in 2001.

The entire grasslands, including the initial herbicide test plots, and forested ravines were helicopter sprayed with Transline at 2/3 pint/acre on October 1, 2004.

Other Weed Treatments

Knapweed biocontrol insects, *Agapeta zoegana* (knapweed root moth) and *Cyphocleonus achates* (knapweed root weevil) were released on the site starting in 1996 (Rice 2000). *Urophora* (knapweed seed head gall flies) species were already well established on the spotted knapweed as of 1994. *Chrysolina* (Klamath weed beetles) were already present on goatweed at the start of the project.

Hand digging, pulling, and limited spot spraying have been used to suppress small colonies of other noxious weeds found on the RNA. The road prisms have also been periodically sprayed with Transline or Tordon.

Burn and Thinning Treatments

The Stevensville Ranger District and the RMRS Fire Sciences Laboratory conducted thinning to reduce competition and ladder fuels and make other broadcast burn preparations in the forested ravines in 1999. Douglas-fir, junipers, and small ponderosa pine were thinned and piled in the west and central forested ravines during the summer. The slash piles, some ladder fuels, and downed logs were burned in the fall of 1999. Some larger Douglas-fir were girdled and left standing to reduce competition, seed supply, and disease source.

The upper two-thirds of the unit was burned on November 7 and 9, 2001. This was primarily grassland habitat types and a small section of forested ravine. The burned forested ravine area included 8 of the 45 forest understory plots.

The forested ravines below the lower road were burned on April 5, 2004 by the Stevensville Ranger District in cooperation with Mick Harrington from the Missoula Fire Sciences Laboratory.

Fuel Sampling

The basic fuel transect is 66 foot long on contour with the slope. The beginning and end of transects are marked with a red rebar. Pre-existing plot/transect markers were used to set up some of the fuel transects. A total of forty-five fuel transects were initially (2001) established. Thirty-five transect were in the two-thirds of the grassland above the lower road. Ten transect were in the third of the grassland below the lower road.

Seventeen additional fuel transects were installed below the road in 2002. Five microplots (10 x 20 inches each) are clipped at predetermined intervals along each transect. The plant material from each microplot is separated into five fuel categories and composites formed at the transect level.

1. All grasses except cheatgrass
2. Cheatgrass
3. Spotted knapweed
4. Other forbs
5. Litter (detached plant material)

Fuel categories 1-4 include all attached plant material even if horizontal on the ground. Samples were forced-air oven dried to a constant weight for three days at 40 degrees Centigrade.

Results

Net standing crops of herbaceous vegetation were estimated by double sampling of full community plots. The measured results are pounds per acre averages of net biomass for study years 1996-1999, 2002, 2004, 2005 and 2006. Average biomass in 2005 was at its highest level recorded in this study and the lowest in 2006. Grasses showed the largest increases in biomass in 2005, but forbs were also at their highest level excluding 2004 values. The decline in total production for 2006 was also measured at numerous other bunchgrass sites being studied by this investigator. Dry and warm weather in May 2006 appears to have arrested growth of perennial grasses, and although June 2006 rainfall was above average these plants did not recover from the May suppression. The large decrease in growth from 2005 to 2006 evidenced by the annual biomass data was confirmed by the canopy cover data (Table 2).

The controls (#918 & 920) were sprayed in the fall of 2004 by drift from the helicopter so there was almost no knapweed growth in 2005 (Table 1). Knapweed on the low rate drift impacted "no-spray" weedy control plots began to recover in 2006. The #920 control had a 96% frequency of occurrence of spotted knapweed, mostly small seedlings, but only 1.7% canopy cover so the knapweed biomass was still suppressed. Plot #907 was substituted in 2006 for #920 as a "no-spray" biomass production control . Plot #907 had been sprayed only once ten years ago in the fall 0f 1996

A four life form summary graph with the production data normalized to remove precipitation determined differences in total annual production is presented as Figure 1; the cheatgrass over time line is based on absolute canopy cover rather than biomass. Perennial grasses showed a large increase in percent of total biomass following both treatments. The knapweed production collapsed to very low levels in the first growing season after the fall 1996 spraying. The partial reestablishment of knapweed in the years following the first treatment was entirely alleviated by the second spray treatment. Even

though non-target forbs showed a small decrease in percent biomass following the first (fall1996) and second (fall 2004) treatment, the overall trend has been for maintenance or an increase in the proportionate biomass of non-target forbs. Because a small amount of cheatgrass is included with other grasses in biomass measurements it is still important to see if the increases in grasses seen after herbicide treatments are also caused by increases in cheatgrass production. Though some cheatgrass has been present in the majority of plots its canopy cover remains ecologically insignificant (~1%) and has not increased at all over the last ten years.

Table 1. Standing crop production summary (lbs/ac. dry weight) for Sawmill test plots.

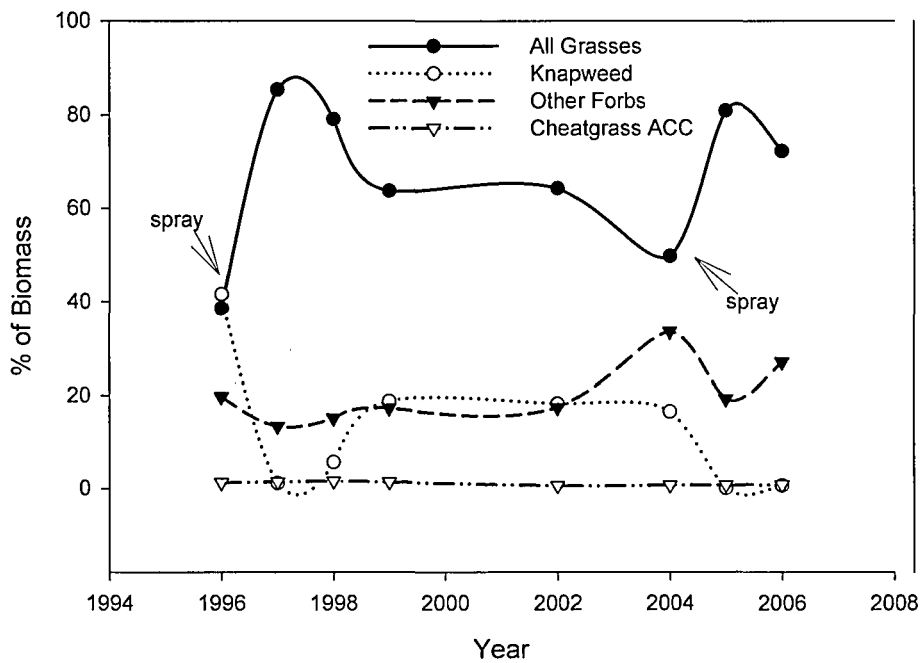
	AGRSPI	FESIDA	FESSCA	*3 Bunch-Grasses	*Other Grasses	All Grasses	CENMAC	Other Forbs	TOTAL
1996 enclosed	228	153	66	447	62	509	473	252	1,234
1996 open	199	87	51	337	76	414	521	220	1,155
Average before spraying	214	120	58	392	69	462	497	236	1,194
1997 enclosed	318	189	147	654	172	826	8	118	951
1997 open	275	123	119	517	283	800	15	138	953
Average one year post spray	297	156	133	586	227	813	11	128	952
1998 enclosed	425	302	244	970	197	1,168	38	193	1,399
1998 open	360	145	132	637	263	900	110	204	1,214
Average 2 years post spray	392	223	188	804	230	1,034	74	199	1,306
1999 enclosed	387	255	141	783	178	961	193	242	1,397
1999 open	343	138	74	556	251	807	330	240	1,377
Average 3 years post spray	365	197	108	669	215	884	262	241	1,387
2002 enclosed	183	178	189	550	54	604	121	159	884
2002 open	223	94	99	416	112	528	200	148	876
Average 6 years post spray	203	136	144	483	83	566	161	154	880
2004 enclosed	204	161	267	632	44	676	171	234	1,081
2004 open	276	105	87	468	68	536	233	585	1,355
Average 8 years post spray	240	133	177	550	56	606	202	409.5	1,218
2005 enclosed	189	614	540	1343	114	1457	0	294	1,751
2005 open	238	296	273	806	179	986	0	288	1,273
Average 1 year post secondary spray	214	455	407	1075	147	1222	0	291	1,512
2006 enclosed	96	85	190	370	47	417	4	132	553
2006 open	105	46	112	262	93	356	2	154	512
Average 2 year post secondary spray	101	67	151	316	70	387	3	143	533
No-spray controls:									
Control, 1999 - #920	8	0	0	8	96	104	1,179	352	1,635
Controls Avg, 2002 #918 & #920	61	0	0	61	100	161	429	101	692
Controls Avg, 2004 #918 & #920	133	1	23	157	143	300	414	105	819
Controls Avg, 2005 #918 & #920†	183	0	0	183	294	478	1	314	793
Controls Avg. 2006 #907 & #918†	45	11	5	60	118	178	281	80	783

*Bunchgrasses are the three habitat type indicator bunchgrasses, Other Grasses are primarily *Koeleria cristata* and *Poa secunda*, except for the no-spray weedy controls which have considerable amounts of cheatgrass (*Bromus tectorum*).

† The controls #918 & #920 received spray drift in the fall of 2004 from the helicopter, #907 was treated only in 1996 and replaced #920 as a "no-spray" control for 2006.

Table 2. Decrease in average canopy cover from 2005 to 2006

Species or Lifeform	2005 Mean C.C.	2006 Mean C.C.	% C.C. Reduction From 2005
AGRSPI	8.2	1.8	78
FESIDA	11.4	2.6	77
FESSCA	15.7	3.4	78
Other Grams	7.0	1.7	76
Other Forbs	9.2	4.3	53



* Values for cheatgrass are calculated from percent absolute canopy cover estimates, not biomass estimates.

Figure 1. Average percent biomass (of total biomass) for grasses, spotted knapweed, and other forbs for eight double sampled test plots sprayed in fall of 1996 and fall 2004; as well as absolute canopy cover of cheatgrass.

The response to spraying the extensive grasslands in fall 1998 with 1 pt/ac Tordon and a second time in fall 2004 with 2/3 pt/ac of Transline were similar to the response on the test plots. The extensive grasslands were sampled by using transects and estimating canopy cover of indicator species and life form groups. These data for the original 14 efficacy transects are summarized in Figure 2.

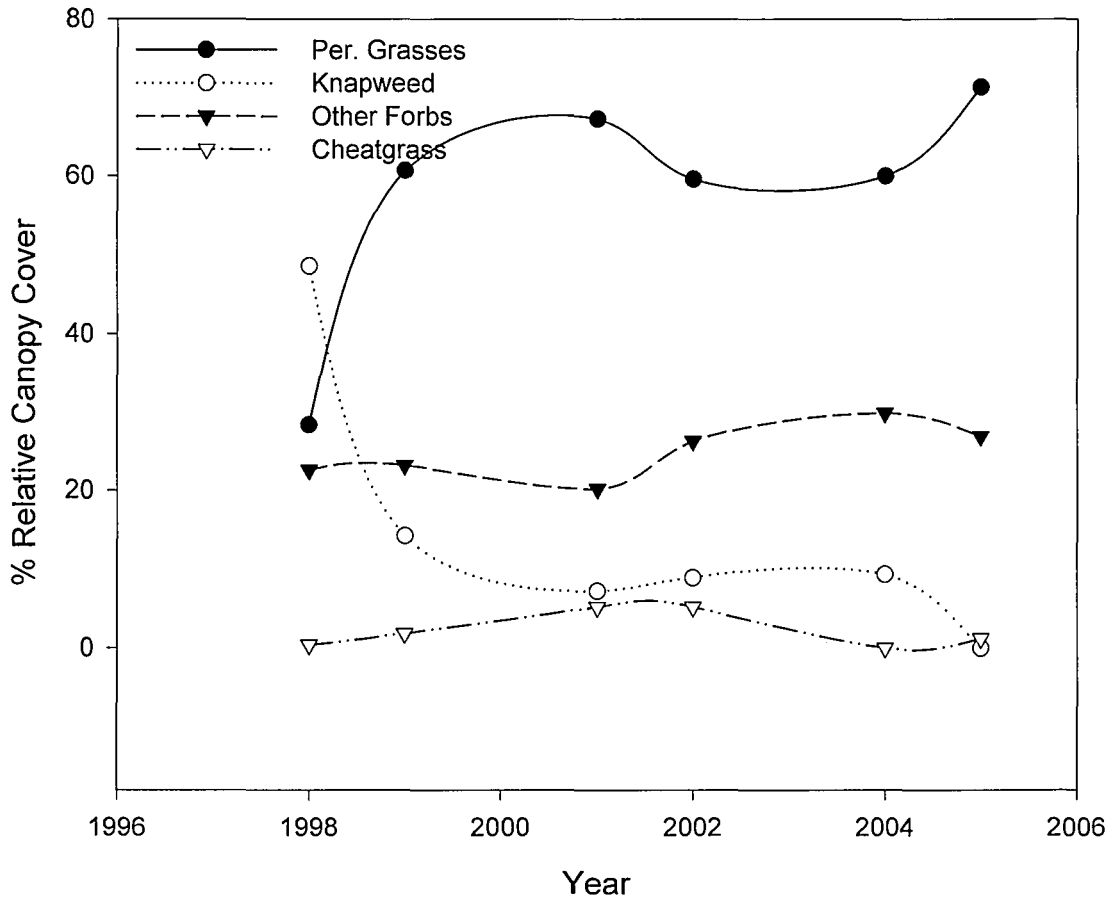


Figure 2. Percent relative canopy cover of four life form groups in the extensive grasslands efficacy/fuel transects following spraying in fall 1998 and fall 2004.

Details of the responses of the extensive grasslands based on the original 14 efficacy transects are summarized in Tables 3 and 4. The fall 2004 Transline treatment did not only greatly reduce the knapweed canopy cover, it additionally reduced the frequency of occurrence to 6% (Table 4) and these occurrences were primarily in the big sagebrush/rough fescue habitat type where the big sagebrush prevented the spray droplets from reaching the spotted knapweed. Frequency of occurrence of other forbs increased greatly in 2004 and 2005, presumably due to more favorable precipitation conditions.

Annual brome species are widespread in the grassland habitat types at the Sawmill RNA, but average canopy cover has remained low throughout the years of monitoring (Table 5). The goatweed plots and the weedy no-spray check plots have had the highest abundances of cheatgrass (Table 6). These areas have the lowest abundances of perennial grasses and are susceptible to cheatgrass flushes following spraying or when rainfall amounts and timing correspond with the early spring primary growth period for cheatgrass.

Table 3. Absolute canopy cover response of vegetation (14 original transects) to extensive grassland Tordon spraying in fall 1998, and secondary Transline treatment in fall 2004.

SPECIES OR LIFE FORM	% CANOPY COVER (ABSOLUTE)					
	1998 (PRE-SPRAY)	1999 (1 YR POST)	2001 (3 YRS POST)	2002 (4 YRS POST)	2004 (5 YRS POST)	2005 (1 YR POST SECONDARY)
CENMAC	25.2	3.0	3.6	1.9	3.4	0.2
BROTEC	0.2	0.4	2.6	1.1	0.3	0.5
ATRTRI	0.5	0.8	1.0	0.5	0.5	0.3
AGRSPI	4.3	4.3	10.3	3.2	7	4.9
FESIDA	5.0	3.8	11.9	4.5	7.8	8.5
FESSCA	3.1	2.7	4.9	1.9	4.8	7.8
O. ANN. GRASSES	0.2	not measured	0.1	0.1	< 0.1	1.5
OTHER FORBS	11.7	4.9	10.1	5.6	10.9	10.9
O. PER. GRASSES	2.3	2.0	6.5	3.1	2.3	7.7
OTHER SHRUBS	<0.1	0.0	<0.1	<0.1	< 0.1	0.3
POTREC	<0.1	0.0	0.0	0.0	0	0

Table 4. Frequency of occurrence response of vegetation (14 original transects) to extensive grassland Tordon spraying in fall 1998, and secondary Transline treatment in fall 2004.

SPECIES OR LIFE FORM	% FREQUENCY OF OCCURRENCE					
	1998 (PRE-SPRAY)	1999 (1 YR POST)	2001 (3 YRS POST)	2002 (4 YRS POST)	2004 (5 YRS POST)	2005 (1 YR POST SECONDARY)
CENMAC	91	26	41	51	51	6
BROTEC	19	16	40	29	26	16
ATRTRI	4	4	4	10	0.5	0.3
AGRSPI	63	54	64	57	57	47
FESIDA	94	87	94	84	79	80
FESSCA	41	43	44	50	44	36
O. ANN. GRASSES	99	93	99	74	4	23
OTHER FORBS	26	not measured	20	21	100	91
O. PER. GRASSES	93	89	89	86	53	91
OTHER SHRUBS	1	0	1	1	1	6
POTREC	1	0	0	0	0	0

Table 5. Overall cheatgrass abundance on test plots sprayed in 1996.

1995-2002		MEAN % CC		CONSTANCY	
Habitat Type	# of Plots	BROJAP	BROTEC	BROJAP	BROTEC
FESIDA/AGRSPI	56	0.1	2.8	36%	95%
FESSCA/FESIDA	16	0.1	1.0	44%	69%
ARTTRI/FESSCA	13	<0.1	0.3	7%	69%
All Years-All Plots		0.1	2.1		

Table 6. Cheatgrass response on various monitoring plots and transects after initial Tordon application, then Transline application to all plot subgroups in fall 2004.

Percent Canopy Cover	N	95	96	97	98	99	01	02	04	05	06
3 pints/acre on goatweed plots in summer 1995	3**	4.9	17.5	16.5	14.9	2.7		4.9	5.6	14.5	4.0
1 pint/acre on experimental plots in fall 1996	13*	1.2			1.9	1.3	3.1	0.6	0.6	0.7	0.7
1 pint/acre on extensive grasslands in fall 1998	14				0.2	0.4	2.6	1.3	0.3	0.5	
No-spray weedy check plots	2	4.5			1.6	1.8	12.8	4.3	5	8.2	7.3
Non-weedy check plots	3	<0.1		0.0				<0.1	0**	0	<0.1
Percent Frequency of Occurrence											
3 pints/acre on goatweed plots in summer 1995	3**	84	96	99	99	99		83	88	85	100
1 pint/acre on experimental plots in fall 1996	13*	30			36	43	45	25	29	21	30
1 pint/acre on extensive grasslands in fall 1998	14				19	16	40	33	2	16	
No-spray weedy check plots	2	92			88	96	80	98	94	92	100
Non-weedy check plots	3	<1		0				1	0**	0	4

N = number of plots or transects comprising sample
* excludes PINPON h.t. plot 907, which has disturbed surface conditions, N was 8 in 2001, 11 in 2006.
** N = 2 instead of three in 2004 & 2006.

Goatweed canopy cover has rebounded to the 1995 pre-spray abundance (Figure 3). Acreage occupied has not been mapped since 1994, but does not appear to have increased beyond the original 4.2 acres and a few small outlier colonies appeared to have been eradicated through 2005 but some goatweed plant reestablishment was observed in 2006. The main colonies were broadcast sprayed in 1995 (3 pt/ac T22K), and spot sprayed at 2 pt/ac in 1997 and 1998. Chrysolina beetle remain abundant on the Sawmill site and are contributing to the goatweed suppression.

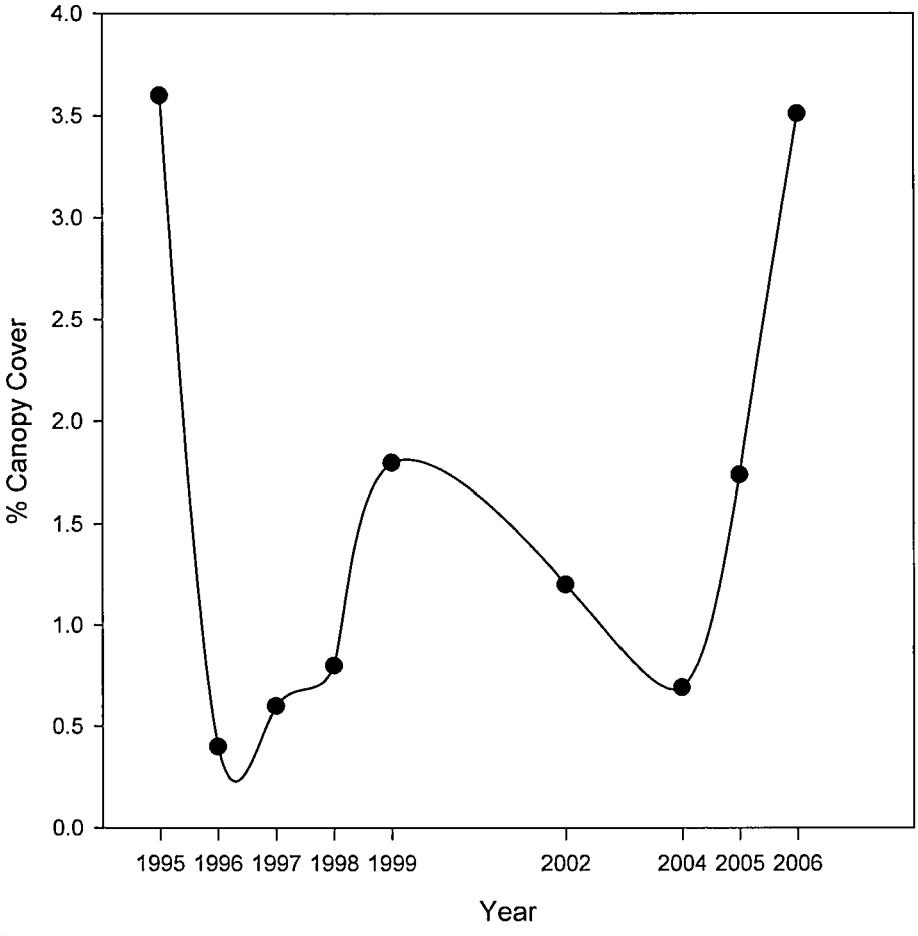


Figure 3. Average goatweed canopy cover on plots #901 and #908.

Other Sampling Completed in 2006

Eighteen experimental full community plots were read in 2006 for all species present (Table 7). These data (canopy cover) have been entered into the study project database and will be analyzed in the winter/spring of 2007 by ordination techniques. A final and all inclusive (1995-2006) technical report will be completed by May 2007.

Table 7. Plot treatment and sampling summary for 0.1 acre experimental test plots, efficacy & fuel transects

plot	enclosed	pair	habitat type	plot type	purpose	road	herbicide	burn	1995	1996	1997	1998	1999	2000	2001	2002	2004	2005	2006	plot
904	y	3	ARTR/FESC	full community	full community	below	tordon Sept 96-1pint, transline Oct 04 2/3 pint		s	n	n	s	s	n	n	s	s	s	s	904
905	n	3	ARTR/FESC	full community	full community	below	tordon Sept 96-1pint, transline Oct 04 2/3 pint		s	n	n	s	s	n	n	s	s	s	s	905
911	y	2	FEID/AGSP	full community	full community	above	tordon Sept 96-1pint, transline Oct 04 2/3 pint	Nov-01	s	n	n	s	s	n	s	s	s	s	s	911
922	n	2	FEID/AGSP	full community	full community	above	tordon Sept 96-1pint, transline Oct 04 2/3 pint	Nov-01	n	s	n	s	s	n	s	s	s	s	s	922
902	y	4	FEID/AGSP	full community	full community	below	tordon Sept 96-1pint, transline Oct 04 2/3 pint		s	n	n	s	s	n	s	s	s	s	s	902
916	n	4	FEID/AGSP	full community	full community	below	tordon Sept 96-1pint, transline Oct 04 2/3 pint		s	n	n	s	s	n	s	s	s	s	s	916
903	n		FEID/AGSP	full community	full community	above	tordon Sept 96-1pint, transline Oct 04 2/3 pint	Nov-01	s	n	n	s	s	n	s	s	s	s	s	903
906	n		FEID/AGSP	full community	full community	above	tordon Sept 96-1pint, transline Oct 04 2/3 pint	Nov-01	s	n	n	s	s	n	s	s	s	s	s	906
910	y	1	FESC/FEID	full community	full community	above	tordon Sept 96-1pint, transline Oct 04 2/3 pint	Nov-01	s	n	n	s	s	n	s	s	s	s	s	910
909	n	1	FESC/FEID	full community	full community	above	tordon Sept 96-1pint, transline Oct 04 2/3 pint	Nov-01	s	n	n	s	s	n	s	s	s	s	s	909
901	n		FEID/AGSP	short nested	goatweed	below	tordon June 95-3pts, transline Oct 04 2/3 pint		s	s	s	s	s	n	n	s	s	s	s	901
908	n		FEID/AGSP	short nested	goatweed	below	tordon June 95-3pts, transline Oct 04 2/3 pint		s	s	s	s	s	n	n	s	s	s	s	908
917	n		PIPO	short nested	goatweed	below	tordon June 95-3pts	out	s	s	s	s	s	n	n	s	s	n	n	917
915	n		ARTR/FESC	short nested	not weedy check	above	nonspray, transline Oct 04 2/3 pint	Nov-01	s	n	n	n	s	n	n	s	n	s	s	915
914	n		FEID/AGSP	short nested	not weedy check	above	nonspray, transline Oct 04 2/3 pint	poor	s	n	n	n	s	n	n	s	s	s	s	914
913	n		FESC/FEID	short nested	not weedy check	above	nonspray, transline Oct 04 2/3 pint	poor	s	n	n	n	s	n	n	s	s	s	s	913
912	n		FEID/AGSP	short nested	short nested	above	tordon Sept 96-1pint, transline Oct 04 2/3 pint	Nov-01	s	n	n	s	s	n	n	s	s	n	n	912
919	n		FEID/AGSP	short nested	short nested	below	tordon Sept 96-1pint, transline Oct 04 2/3 pint		s	n	n	s	s	n	n	s	s	s	n	919
907	n		PIPO	short nested	short nested	below	tordon Sept 96-1pint, transline Oct 04 2/3 pint	out	s	n	n	s	s	n	n	n	s	s	s	907
921	n		PSME	short nested	short nested	above	tordon Sept 96-1pint, transline Oct 04 2/3 pint	out	s	n	n	s	s	n	n	n	s	n	n	921
918	n		FEID/AGSP	short nested	weedy check	below	nonspray		s	n	n	n	s	n	s	s	s	s	s	918
920	n		FEID/AGSP	short nested	weedy check	below	nonspray, transline Oct 04 2/3 pint		s	n	n	s	s	n	s	s	s	s	s	920
923	n	L,R	ARTR/FESC	Transect pair	elk pellets, spray efficacy	below	Tordon Oct 98-1pint, transline Oct 04 2/3 pint				sp*	sp, se*	sp, se	n	se	se	se	se	n	923
924	n	L,R	FEID/AGSP	Transect pair	elk pellets, spray efficacy	below	Tordon Oct 98-1pint, transline Oct 04 2/3 pint				sp	sp, se	sp, se	n	se	se	se	se	n	924
925	n	L,R	FEID/AGSP	Transect pair	elk pellets, spray efficacy	above	Tordon Oct 98-1pint, transline Oct 04 2/3 pint	Nov-01			sp	sp, se	sp, se	n	se	se	se	n	n	925

plot	enclosed	pair	habitat type	plot type	purpose	road	herbicide	burn	1995	1996	1997	1998	1999	2000	2001	2002	2004	2005	2006	plot
926	n	L,R	FEID/AGSP	Transect pair	elk pellets, spray efficacy	above	Tordon Oct 98-1pint, transline Oct 04 2/3 pint	Nov-01			sp	sp, sc	sp, sc	n	sc	se	se	se	n	926
927	n	L,R	FESC/FEID	Transect pair	elk pellets, spray efficacy	above	Tordon Oct 98-1pint, transline Oct 04 2/3 pint	Nov-01			sp	sp, sc	sp, sc	n	sc	se	se	se	n	927
928	n	L,R	FEID/AGSP	Transect pair	elk pellets, spray efficacy	above	Tordon Oct 98-1pint, transline Oct 04 2/3 pint	poor			sp	sp, sc	sp, sc	n	sc	se	se	se	n	928
929	n	L,R	PSME	Transect pair	elk pellets, spray efficacy	above	Tordon Oct 98-1pint, transline Oct 04 2/3 pint	out			sp	sp, sc	sp, sc	n	sc	n	se	se	n	929
930	n			fuel transect	fuels, burn response	above	Tordon Oct 98-1pint, transline Oct 04 2/3 pint	Nov-01							se	se	se	se	n	930
931	n			fuel transect	fuels, burn response	above	Tordon Oct 98-1pint, transline Oct 04 2/3 pint	Nov-01							se	se	se	se	n	931
932	n			fuel transect	fuels, burn response	above	Tordon Oct 98-1pint, transline Oct 04 2/3 pint	Nov-01							se	se	se	se	n	932
933	n			fuel transect	fuels, burn response	above	Tordon Oct 98-1pint, transline Oct 04 2/3 pint	Nov-01							se	se	se	se	n	933
934	n			fuel transect	fuels, burn response	above	Tordon Oct 98-1pint, transline Oct 04 2/3 pint	Nov-01							se	se	se	se	n	934
935	n			fuel transect	fuels, burn response	above	Tordon Oct 98-1pint, transline Oct 04 2/3 pint	Nov-01							se	se	se	se	n	935
936	n			fuel transect	fuels, burn response	above	Tordon Oct 98-1pint, transline Oct 04 2/3 pint	Nov-01							se	se	se	se	n	936
937	n			fuel transect	fuels, burn response	above	Tordon Oct 98-1pint, transline Oct 04 2/3 pint	Nov-01							se	se	se	se	n	937
938	n			fuel transect	fuels, burn response	above	Tordon Oct 98-1pint, transline Oct 04 2/3 pint	Nov-01							se	se	se	se	n	938
939	n			fuel transect	fuels, burn response	above	Tordon Oct 98-1pint, transline Oct 04 2/3 pint	Nov-01							se	se	se	se	n	939
940	n			fuel transect	fuels, burn response	above	Tordon Oct 98-1pint, transline Oct 04 2/3 pint	Nov-01							se	se	se	se	n	940
941	n			fuel transect	fuels, burn response	above	Tordon Oct 98-1pint, transline Oct 04 2/3 pint	Nov-01							se	se	se	se	n	941
942	n			fuel transect	fuels, burn response	above	Tordon Oct 98-1pint, transline Oct 04 2/3 pint	Nov-01							se	se	se	se	n	942
943	n			fuel transect	fuels, burn response	above	Tordon Oct 98-1pint, transline Oct 04 2/3 pint	Nov-01							se	se	se	se	n	943
944	n			fuel transect	fuels, burn response	above	Tordon Oct 98-1pint, transline Oct 04 2/3 pint	Nov-01							se	se	se	se	n	944
945	n			fuel transect	fuels, burn response	above	no weeds, transline Oct 04 2/3 pint	Nov-01							se	se	se	se	n	945
946	n			fuel transect	fuels, burn response	above	no weeds, transline Oct 04 2/3 pint	no							se	se	se	se	n	946
947	n			fuel transect	fuels, burn response	above	no weeds, transline Oct 04 2/3 pint	no							se	se	se	se	n	947
948	n			fuel transect	fuels, burn response	above	no weeds, transline Oct 04 2/3 pint	no							se	se	se	se	n	948
949	n			fuel transect	fuels, burn response	above	no weeds, transline Oct 04 2/3 pint	Nov-01							se	se	se	se	n	949

plot	enclosed	pair	habitat type	plot type	purpose	road	herbicide	burn	1995	1996	1997	1998	1999	2000	2001	2002	2004	2005	2006	plot
950	n			fuel transect	fuels, burn response	above	no weeds, transline Oct 04 2/3 pint	Nov-01							se	se	se	se	n	950
951	n			fuel transect	fuels, burn response	below	low, steep, transline Oct 04 2/3 pint								se	se	se	se	n	951
952	n			fuel transect	fuels, burn response	below	low, steep, transline Oct 04 2/3 pint								se	se	se	se	n	952
953	n			fuel transect	fuels, burn response	below	?Tordon Oct 98-1pint, transline Oct 04 2/3 pint									se	se	se	n	953
954	n			fuel transect	fuels, burn response	below	?Tordon Oct 98-1pint, transline Oct 04 2/3 pint									se	se	se	n	954
955	n			fuel transect	fuels, burn response	below	?Tordon Oct 98-1pint, transline Oct 04 2/3 pint									se	se	se	n	955
956	n			fuel transect	fuels, burn response	below	?Tordon Oct 98-1pint, transline Oct 04 2/3 pint									se	se	se	n	956
957	n			fuel transect	fuels, burn response	below	?Tordon Oct 98-1pint, transline Oct 04 2/3 pint									se	se	se	n	957
958	n			fuel transect	fuels, burn response	below	?Tordon Oct 98-1pint, transline Oct 04 2/3 pint									se	se	se	n	958
959	n			fuel transect	fuels, burn response	below	?Tordon Oct 98-1pint, transline Oct 04 2/3 pint									se	se	se	n	959
960	n			fuel transect	fuels, burn response	below	?Tordon Oct 98-1pint, transline Oct 04 2/3 pint									se	se	se	n	960
961	n			fuel transect	fuels, burn response	below	?Tordon Oct 98-1pint, transline Oct 04 2/3 pint									se	se	se	n	961
962	n			fuel transect	fuels, burn response	below	?Tordon Oct 98-1pint, transline Oct 04 2/3 pint									se	se	se	n	962
963	n			fuel transect	fuels, burn response	below	?Tordon Oct 98-1pint, transline Oct 04 2/3 pint									se	se	se	n	963
964	n			fuel transect	fuels, burn response	below	?Tordon Oct 98-1pint, transline Oct 04 2/3 pint									se	se	se	n	964
965	n			fuel transect	fuels, burn response	below	?Tordon Oct 98-1pint, transline Oct 04 2/3 pint									se	se	se	n	965
966	n			fuel transect	fuels, burn response	below	?Tordon Oct 98-1pint, transline Oct 04 2/3 pint									se	se	se	n	966
967	n			fuel transect	fuels, burn response	below	?Tordon Oct 98-1pint, transline Oct 04 2/3 pint									se	se	se	n	967
968	n			fuel transect	fuels, burn response	below	?Tordon Oct 98-1pint, transline Oct 04 2/3 pint									se	se	se	n	968
969	n			fuel transect	fuels, burn response	below	?Tordon Oct 98-1pint, transline Oct 04 2/3 pint									se	se	se	n	969

Treatments Completed (2004 & 2005):

All planned treatments were completed except the burning of the lower grassland, which could not be burned because of insufficient quality fuel.

1. The forested ravines below the lower road were burned on April 5, 2004 by the Stevensville Ranger District in cooperation with Mick Harrington from the Missoula Fire Sciences Laboratory.
2. The grasslands and forested ravines were helicopter sprayed with Transline at 2/3 pint/acre on October 1, 2004.
3. Flowerheads were clipped on August 3, 2004 at the nine dalmatian toadflax colonies with regrowth, then the leaves and stems were backpack sprayed with 12 oz/acre Plateau plus 1 qt/acre methylated seed oil on November 8, 2004.
4. Flowerheads were clipped on July 30, 2005 at the nine dalmatian toadflax colonies with regrowth, then the leaves and stems were backpack sprayed with 12 oz/acre Plateau plus 1 qt/acre methylated seed oil on October 12, 2005.

Sampling Completed (2005):

All planned sampling was completed.

1. Thirty-two fuel transects below the lower road were sampled for five fuel classes in March of 2005 to determine if a spring burn would be feasible.
2. Twenty-two 1/10 acre permanent plots were sampled for full community composition and ground cover.
3. Ten permanent plots were double sampled and weighted for production estimates.
4. The fifty-four fuel/efficacy transects scattered through the grasslands were sampled for canopy cover of weeds, cheatgrass, indicator grasses, and life form groups.
5. Forty-five permanent forest understory plots were sampled for species canopy cover and ground cover.